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No. 65

REGIONAL RESEARCH
LABORATORIES
DEPARTMENT OF AGRICULTURE

LETTER

FROM THE

SECRETARY OF AGRICULTURE

TRANSMITTING

A REPORT OF A SURVEY MADE BY THE DEPARTMENT
OF AGRICULTURE RELATIVE TO FOUR REGIONAL
RESEARCH LABORATORIES, ONE IN EACH
MAJOR FARM PRODUCING AREA

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APRIL 6, 1939.—Referred to the Committee on Agriculture and Forestry

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1939

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LABORATORIES
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Submitted by Mr. BILBO

[Senate Resolution No. 122]

IN THE SENATE OF THE UNITED STATES,
April 19, 1939.

RESOLUTION

Resolved, That the letter of the Secretary of Agriculture dated April 5, 1939, which was transmitted to the Senate and referred to the Committee on Agriculture and Forestry on April 6, 1939, together with a report of a survey of all research activities relating to the industrial utilization of agricultural products in the four regional areas to be served by the regional laboratories, one in each major farm producing area, and to conduct researches into and develop new scientific, chemical, and technical uses, and new and extended markets and outlets for farm commodities and products, and byproducts thereof, together with the accompanying papers and illustrations, be printed as a Senate document; and that two thousand additional copies be printed for the use of the Senate Document Room.

Attest:

EDWIN A. HALSEY, *Secretary*.

LETTER OF TRANSMITTAL

DEPARTMENT OF AGRICULTURE,
Washington, April 5, 1939.

THE PRESIDENT OF THE SENATE.

SIR: In the Agricultural Adjustment Act of 1938 Congress provides that "the Secretary [of Agriculture] is hereby authorized and directed to establish, equip, and maintain four regional research laboratories, one in each major farm producing area, and, at such laboratories, to conduct researches into and to develop new scientific, chemical, and technical uses and new and extended markets and outlets for farm commodities and products and byproducts thereof. Such research and development shall be devoted primarily to those farm commodities in which there are regular or seasonal surpluses, and their products and byproducts." (Public, No. 430, 75th Cong.)

In the discussion of the appropriations for the four regional research laboratories, Congress raised certain questions regarding the present status of research in the field of industrial utilization of agricultural commodities and provided that "not to exceed \$100,000 shall be available under the provisions of sections 202 (a) to 202 (e), inclusive, of said act [the Agricultural Adjustment Act of 1938] to conduct a survey to determine the location of said [regional research] laboratories and the scope of the investigations to be made and to coordinate the research work now being carried on." (Public, No. 644, 75th Cong., H. R. 10238.)

In accordance with this provision in the Appropriation Act, a special survey committee was appointed, with the following instructions:

(1) To conduct a survey of all research activities relating to the industrial utilization of agricultural products in the four regional areas to be served by the regional laboratories, such survey to include a study of the research projects of the Department of Agriculture and other Federal agencies, the State experiment stations, educational institutions, privately endowed research institutions, commercial consulting research laboratories, and the research laboratories maintained by industries based wholly or in part on utilization of agricultural raw materials, and report their findings to the Department.

(2) To assemble facts bearing upon suitability of proposed laboratory locations and make report thereon to the Department.

(3) To make recommendations to the Department as to the scope of investigations to be undertaken in these laboratories, and as to ways in which the research recommended may be coordinated with other activities in the same field.

The special survey committee, with the cooperation of administrative officers and specialists throughout the Department of Agriculture, has organized and conducted the survey of active research. During the survey, specialists of the Department have personally interviewed representatives of 1,300 research institutions, including

about 1,100 industrial research laboratories. In almost every case the investigators have received the heartiest cooperation and expressions of approval of the general objectives of the legislation as they relate to new outlets for surplus farm commodities.

With a few outstanding exceptions, the results of the survey indicate that the major objectives of research in industry are directed to the immediate application of science to the improvement of quality and to effect economies associated with customary uses. Industrial research has resulted in greatly expanded use and broadened outlets for nonagricultural raw materials; but that has not been true of nonfood uses and outlets for the products of the farm. The extent to which agricultural products may enter this field of use will depend upon complete and reliable information as to the physical and chemical qualities required for industrial uses, the practical possibilities of their conversion into marketable products, and assurance of the supply of raw materials at costs comparable to other sources of raw materials. It would seem, therefore, that if farm commodities are to find new outlets through industrial utilization, some means must be provided for research and investigation directed to this purpose, as has been authorized by section 202 of the Agricultural Adjustment Act of 1938.

The research in the Department, in the experiment stations, and in the educational institutions also was reviewed to determine more closely its relation to the objective for which Congress directed the establishment of regional laboratories. This research, with only incidental exceptions, is directed toward objectives other than the development of new industrial uses for farm products. The results of this research, however, have contributed much information on the chemical and physical properties of a number of agricultural products, the agronomic factors which determine some of these properties, present and potential supply of such products, etc. All this information, it is believed, will contribute materially toward strengthening the work for which Congress established the laboratories. In short, many lines of research that have been pursued over a number of years with objectives primarily different from those of new industrial uses, have contributed information which will be highly useful in the new undertaking. The research which Congress had in mind for these laboratories, perhaps with minor exceptions, is not being duplicated by existing research programs. Such exceptions as there may be to this general conclusion will be subject to appropriate administrative adjustment in relation to the new laboratory program when that program is under way.

In assembling facts bearing upon the advantages of proposed laboratory locations, consideration was given to the claims of more than 200 towns and cities filing applications with the Department of Agriculture. More than 80 points throughout the United States were visited to assemble the data which guided the selection of the locations.

The research objectives outlined in section 202 of the Agricultural Adjustment Act of 1938 are recognized as a distinct addition to the present major research objectives of the Department of Agriculture. With this in mind, there has been prepared (pt. III of the attached report) a program of research on the surplus commodities designated for initial research attention in my announcement of August 15, 1938. The program is so broadly formulated as to show the many desirable cooperative contacts with existing research in the Department and

the State experiment stations. It also indicates the means by which cooperation and coordination, as provided in the statute quoted in the beginning of this letter, will be accomplished.

In the proposed research program of the four regional research laboratories, the Department has recognized the fact that this research attack represents but one part of the Government's general program dealing with agricultural surpluses. As is well known to the Congress, this problem has already been engaged on a wide front, including production adjustment through a Nation-wide conservation activity; expansion of foreign outlets through trade agreements and quality improvement of products exported; surplus disposal in the domestic market, with diversion of surplus for relief purposes; and improvement in marketing methods and practices. The opening up of new industrial markets for farm products is a field that urgently needs further exploring. These new laboratories will make possible a major effort in that direction.

The report of the survey is submitted herewith.

Sincerely,

H. A. WALLACE,
Secretary.

Enc.

This report was prepared under the direction of the following committee, appointed by the Secretary of Agriculture in Memorandum No. 765, dated July 14, 1938:

H. T. HERRICK, Bureau of Chemistry and Soils, *Chairman*.

P. V. CARDON, Bureau of Plant Industry.

A. B. GENUNG, Bureau of Agricultural Economics.

R. Y. WINTERS, Office of Experiment Stations.

The following members of the Bureau of Chemistry and Soils were in charge of the survey for the four regional producing areas:

O. E. MAY, Northern Producing Area.

D. F. J. LYNCH, Southern Producing Area.

P. A. WELLS, Eastern Producing Area.

T. L. SWENSON, Western Producing Area.

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A SURVEY OF AND PROPOSED PROGRAM FOR RESEARCH ON THE INDUSTRIAL UTILIZATION OF AGRICULTURAL PRODUCTS

FOREWORD

In 1938 Congress directed the Secretary of Agriculture to establish four regional research laboratories which should undertake, by research, to develop new and extended uses for surplus farm commodities. This provision is in section 202 of the Agricultural Adjustment Act of 1938. By the Agricultural Appropriation Act for the fiscal year ending June 30, 1939, Congress also provided for "a survey to determine the location of said laboratories and the scope of the investigations to be made and to coordinate the research work now being carried on." In compliance with these acts the Department of Agriculture has determined the major producing areas of the Nation, designated the farm commodities that will receive initial research attention, and conducted the survey concerned with laboratory locations, active and proposed research, and coordination of research work.

Research on the surplus commodities concerned may be of many sorts. The plans for the new regional laboratories will be directed particularly to the carrying out of the mandate of Congress to discover new and enlarged uses for agricultural products by means of scientific studies. This, it is hoped, will result in new industrial activity of varied types. The research work is, in fact, planned merely as an agency by which such increased utilization may be developed as will regularly use the kinds of commodities now in surplus.

To comply with the second instruction of Congress, to survey present investigations and coordinate research work, the Department of Agriculture organized a special staff of experienced field investigators. The members of this staff visited every State and interviewed representatives of about 1,300 research laboratories, educational institutions, and agricultural organizations. There were thus obtained from over 1,000 different industrial groups, as well as from all educational and endowed institutions interested, a fairly complete knowledge of present activities along this line in the United States and many hundreds of suggestions regarding needed research work.

For convenience the material in this report is presented in four main parts:

Part I summarizes some of the general aspects of the present situation, the methods and objects of the survey and some of its findings, the plans for establishment of the regional laboratories, and the proposed initial research program.

Part II presents in some detail the results of the survey, including both reports of the character and scope of most of the present research activities in the country having to do with industrial use of farm products and the large number of suggestions obtained regarding new

and needed investigations. These reports and suggestions are arranged by commodity groups, as listed in the introduction to part II. Not only those commodities in surplus but also other products of agriculture on which investigations were recommended are covered.

Part III presents the program for the initial work of the new regional research laboratories, and the principles of the coordination of that work with existing research effort.

Part IV is an acknowledgment to those organizations and individuals cooperating with the Department of Agriculture in the survey.

In both the survey of research and the formulation of programs the Department of Agriculture has had the assistance and cooperation of a very large number of those engaged in like work throughout the Federal and State organizations, in the universities and colleges, and in the research staffs of industry. The response of all groups to the request for suggestions and assistance has been very gratifying. The Secretary of Agriculture is pleased to report to the Congress that almost without exception the survey investigators were met not only with a cooperative spirit, but also with general expressions of encouragement and approval for the plans of the new laboratories. Experienced directors of research have repeatedly expressed their approval of this new plan for an aggressive Nation-wide attack on the surplus problem by the Federal Government. The decision of Congress to establish these laboratories in order to determine new ways in which products of agriculture may be more extensively used in industry has been received with very general favor.

Plans for construction of the buildings required for the four regional laboratories are being completed, and contracts for erection will soon be let. A nucleus for the senior staff of each of the laboratories is to be named shortly from a list of eligible scientists now being prepared under civil-service regulations. Detailed plans for coordinated experimental work will receive careful consideration and laboratory investigations will be taken up as soon as the buildings can be completed and the necessary apparatus installed. Annual reports will be made to Congress as is customary for the research work of the Department of Agriculture.

PART I. GENERAL STATEMENT

THE SURPLUS PROBLEM

The regional research laboratories, authorized by Congress in 1938, will make a further direct attack upon the surplus problem of agriculture. As is well known to the Congress, this problem already has been engaged upon a wide front, including basic efforts to stabilize production in line with the apparent needs of the markets. But the opening up of new consuming outlets for farm products is a field that urgently needs further exploring. These new laboratories will make possible a major effort in that direction.

The surplus problem has had its origin in the field of consumption, as well as in overproduction. Circumstances dating from the World War, including the loss of important export markets, played a major part in bringing the situation to an acute stage. For many years before the World War, this country was accustomed to sell abroad some 150 to 200 million bushels of wheat, 8 to 9 million bales of cotton, and well toward a billion pounds of pork, in addition to fairly large quantities of tobacco and fruit. In other words, our production of these important items was geared to a substantial foreign demand as well as to a rapidly expanding domestic market.

During the World War, prices and production were further stimulated by financial inflation. Then, after the war, came the period of deflation, with its accompanying crash in commodity prices. Farm products and other raw materials were especially hard hit. European buying was curtailed, and huge unwanted stocks of American pork, wheat, and cotton piled up on the farms and in trade channels.

On the producing end, there have been enormous strides taken in the direction of increasing the output of our farms per hour of labor, per acre, and per animal unit. This has gone on in all agricultural countries, but especially in the United States. Improvement in methods of tillage, in varieties of plants, and in productivity of animals during the last 30 to 50 years has infinitely surpassed that in any like period in history.

One of the most potent of the factors entering into this surplus production has been the mechanization of agriculture. This has been one of those developments that causes economic change faster than men can adjust their enterprises to the new situation. The impressive fact is that the technique of agricultural production has advanced more in the last 50 years than it did in 50 centuries previously. The new mechanized agriculture has helped to step up production until markets of the whole world frequently have been ridden by accumulated supplies of staple food and fiber products—an interesting contradiction of the forecasts of shortages made a generation ago by eminent scientists. In this country, crop production per agricultural worker has increased nearly two and one-half times during the last 90 years, and total agricultural production per worker of crops and animals apparently has increased about threefold. This improvement

has not ceased. Since 1920 alone, agricultural production per worker has increased probably 30 to 35 percent.

Unfortunately, the full fruit of all this remarkable forward sweep in agricultural productivity was realized at the very time when the accustomed channels of consumption were being changed or disrupted. The impact of increased supplies upon a shrunken market meant lower prices and more distress for our farmers. Finally came the inevitable sequel of land thrown out of use and farm workers out of employment.

The low ebb of prices gives us the best measure of surpluses, for in our modern commercial system price has become an all-important economic gage. It is, in fact, impossible to separate the modern concept of surplus from the question of price. A price relationship that will induce the farmer to maintain production and will at the same time permit him to maintain progressive business and living standards would presumably be satisfactory. Any quantity of production that depresses the price below that level presumably is to be defined as "surplus."

It is important at the time of founding of the new regional laboratories to recognize that they are grappling with what will be a continuing problem, one that will have to be met by continuing helpful programs. It is hoped that with improved world trade, for example, some of the aggravating causes of surpluses may diminish; but other causal factors are as likely to grow. The underlying trends that have developed in our economy and in our national pattern of agricultural production have, it is plain, brought permanent changes. It is in recognition of this fact that a program of research is formulated for these laboratories, so that they may carry forward a logical continuing attack on a long-time problem.

THE NEW REGIONAL RESEARCH LABORATORIES

In section 202 of the Agricultural Adjustment Act, approved February 16, 1938, Congress provided as follows:

The Secretary (of Agriculture) is hereby authorized and directed to establish, equip, and maintain four regional research laboratories, one in each major farm producing area, and at such laboratories to conduct researches into and to develop new scientific, chemical, and technical uses and new and extended markets and outlets for farm commodities and products and byproducts thereof. Such research and development shall be devoted primarily to those farm commodities in which there are regular or seasonal surpluses, and their products and byproducts.

In the appropriations act providing funds for the current fiscal year Congress also instructed the Department—

to conduct a survey to determine the location of said laboratories and the scope of the investigations and to coordinate the research work now being carried on. For this purpose a sum not to exceed \$100,000 was made available. Thus Congress provided for an elaborate reconnaissance on which among other things a sound and comprehensive research program for surplus commodities is to be based. The results of the completed survey are given in part II of this report.

The major purpose in establishing these laboratories was to provide an agency of the Department of Agriculture which will devote itself exclusively to further research on the products of agriculture on which new and extended industrial uses may develop. The further commer-

cialization of the products of agriculture and the creation of new markets for surplus commodities of this sort is expected to result. This is not an entirely new activity, but it will represent the first large-scale attack which the Department has been able to make using scientific and economic research as agents for the creation of new industrial markets. Part III of this report shows the general way in which the Department proposes to coordinate the new activity with present agricultural research.

NEED FOR LABORATORIES

The products of agriculture are used more for food than for any other single purpose. Textile uses of such commodities as cotton and other fiber crops are second in dollar importance to the farmer. To a considerable extent, however, industrial processing of farm products has led to nonfood and nonfabric applications. The principles which have in the past enabled such successful development of the latter types will largely assist in the planning of new possibilities of like nature. A few examples will aid in understanding these.

Although corn is used primarily as animal feed by those farmers who grow it, there has been during recent years a constantly increasing use of corn as an industrial raw material. About 3 percent of the total crop, some 80,000,000 bushels per year, is now processed for the manufacture of starch, oil, and other products, with a large part of the starch being used industrially and not in foods. Although this quantity is a small part of the total crop, it forms nearly a third of the corn that is sold by farmers, and therefore very largely increases the farmer's opportunity to obtain cash for his crop.

The products made from corn are in some ways of quite different significance from the products made from certain other agricultural materials, cottonseed for example. Cottonseed was at one time merely a waste, if not a nuisance. Then processing for the recovery of cottonseed oil began. Now the cash value of the seed equals about 16 percent of the total cotton-crop value.

Numerous other important developments have occurred in the use of agricultural raw materials. For example, synthetic fibers and other cellulose plastics are manufactured in large quantities from cotton linters. Such chemicals as acetone, butyl alcohol, and others are made by controlled fermentation of corn. The chemical furfural is made from waste oat hulls by processes which originated in the Department laboratories. The wide variety of industrial products that have been made from products which were surpluses of agriculture is illustrated by these and many other examples. This experience not only justifies more research of like nature in the new regional laboratories, but also affords an important guide for the planning of the projects to be carried out there.

Such developments as these benefit both agriculture and industry, for they afford new opportunity for factory employment as well as new markets for the farmer.

DEFINITION OF REGIONS, OR AREAS

In its provisions for the regional laboratories, Congress instructed the Secretary of Agriculture to divide the country into four "major farm producing areas." One regional laboratory is to be established

in each such area; and one-fourth of the funds made available for the group is to be allocated to each such laboratory.

In grouping the States for the purposes of this act the Department took into account a number of important criteria. Of first importance were the natural boundaries fixed by the habits of agriculture in growing the most important crops. But a grouping that would follow such crop areas exactly is not possible because of the overlapping of these areas and variation in agricultural conditions in different parts of the country. Other important criteria considered were, therefore: Farm population, value of farm property, cash income from crops and livestock, land in farms, and total land areas. The quantitative significance of these criteria is shown in table 1 and the accompanying map.

TABLE 1.—*Farm population, value of farm property, cash income from farm production, land in farms, and total land area, United States and four regions, specified years*

Item	Year	Unit	Amounts by regions				
			United States	Southern	Eastern	Northern	Western
Farm population.....	1935	Thousands.....	31,801	10,781	8,761	9,877	2,382
Value of farm property...	1930	Million dollars.....	57,246	9,754	9,568	29,263	8,661
Cash income from crops and livestock ¹	1937	Million dollars.....	8,233	1,650	1,718	3,439	1,426
Land in farms.....	1935	Million acres.....	1,055	284	144	390	237
Total land area.....	1935	Million acres.....	1,903	430	236	484	753

Item	Year	Percentage by regions				
		United States	Southern	Eastern	Northern	Western
Farm population.....	1935	Percent 100	Percent 34	Percent 28	Percent 31	Percent 7
Value of farm property.....	1930	100	17	17	51	15
Cash income from crops and livestock ¹	1937	100	20	21	42	17
Land in farms.....	1935	100	27	14	37	22
Total land area.....	1935	100	23	12	25	40

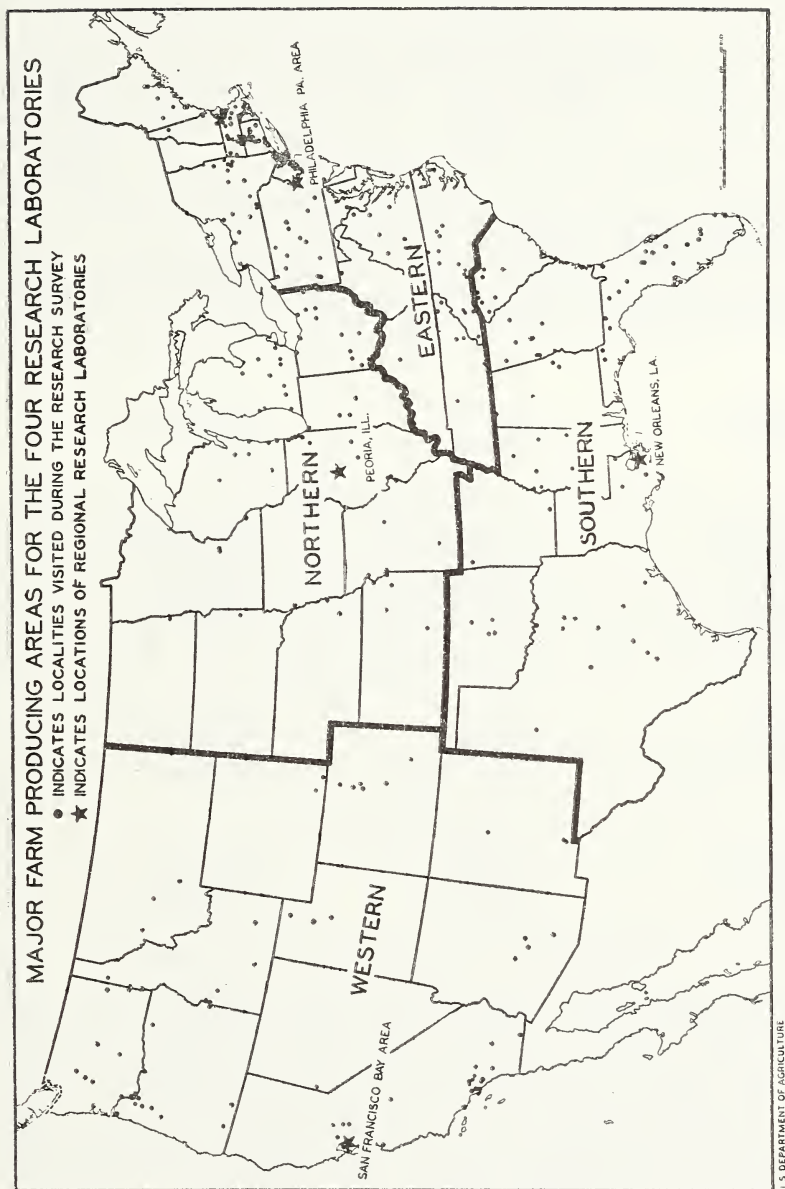
¹ Excluding Government payments.

The regions, or areas, as defined in table 1 are fairly well balanced when judged according to various essential criteria.

The farm population of the country, tabulated for these four areas, gives no region less than 7 percent of the population nor more than 34 percent.

No area has such a small percentage of the total value of farm property as to be below what might reasonably be called a major farming area according to the criterion of total farm value; nor does any area include such an overwhelmingly large percentage of the total farm value as to suggest that it dominates all others from the standpoint of this criterion.

The same may be said with respect to the distribution of cash income. Crop income is fairly evenly divided among the southern, eastern, and western areas. The northern area, with 42 percent of the total cash income, is not considered excessively large for one region when taking into account other criteria shown in the table, especially considering the type of agriculture and surplus problems found there.



Although the eastern area has only 14 percent of the land in farms, it has 28 percent of the farm population. Conversely, the western area is the largest geographically, but the smallest in farm population. There is less divergence of these important factors according to the designated division among the four areas than would be true with any other reasonably practicable grouping of the States.

From the standpoint of the laboratories themselves it was important that the areas be formed so as to balance the research load of the four laboratories. In this connection it should be recalled that by law funds must be allocated equally among the four. This consideration made it desirable, for example, to put tobacco research in the eastern laboratory. To have put it in the southern laboratory, which might be equally logical, would have reduced the effectiveness of work on other important commodities of that area.

The following grouping of States has been determined as a basis for the definition of "major farm producing areas," and one regional laboratory is being established in each area:

THE SOUTHERN AREA

Alabama	Georgia	Oklahoma
Arkansas	Louisiana	South Carolina
Florida	Mississippi	Texas

THE EASTERN AREA

Connecticut	New Hampshire	Rhode Island
Delaware	New Jersey	Tennessee
Kentucky	New York	Vermont
Maine	North Carolina	Virginia
Maryland	Pennsylvania	West Virginia
Massachusetts		

THE NORTHERN AREA

Illinois	Minnesota	Ohio
Indiana	Missouri	South Dakota
Iowa	Nebraska	Wisconsin
Kansas	North Dakota	Michigan

THE WESTERN AREA

Arizona	Montana	Utah
California	Nevada	Washington
Colorado	New Mexico	Wyoming
Idaho	Oregon	

ASSIGNMENT OF COMMODITIES TO REGIONS

All of the important farm commodities produced in the United States are from time to time in surplus. The Department of Agriculture might, therefore, under the instructions of Congress, consider in the new regional laboratories almost any of these products of agriculture. To do so, however, would so scatter the effort as to make early and useful results improbable. The Department has planned, therefore, that it should take up initially in each of the four laboratories only a limited number of commodities.

Those which seem most urgently in need of attention either because of the magnitude of the surpluses or because of the large number of agricultural workers or agricultural acres involved will be studied first.

The commodities that are to have first attention by research have been designated as follows:

Southern area:	Eastern area—Continued.
Cotton.	Irish potatoes.
Sweetpotatoes.	Milk products.
Peanuts.	Vegetables.
Northern area:	Western area:
Corn.	Fruits and vegetables.
Wheat.	Irish potatoes.
Agricultural waste products.	Wheat.
Eastern area:	Alfalfa.
Tobacco.	
Apples.	

The fact that any particular commodity does not appear on this list is no indication that the Department does not believe it important or does not believe that research on it would be profitable. Quite the contrary is true of many of the agricultural products; and it is expected that the regional laboratories will in due time give attention to many more classes of commodities than can be subjects of the initial research.

THE SURVEY

SURVEY OF PRESENT RESEARCH

To carry out the instructions of Congress for a preliminary survey of present research as a basis for a coordinated program of new work, the Department organized a special survey committee including representatives of several of the bureaus most concerned with this type of work. A technical staff experienced in scientific investigations was organized and a comprehensive plan laid for reviewing all the present activities of the Department, of the experiment stations and other State agencies, and of such industries and institutions as are engaged on comparable or related work.

Records were obtained by this committee from all the bureaus of the Department of Agriculture and from such other Federal agencies as are engaged on related types of work. Reports were made to the Department by every State experiment station; and personal visits were made by the survey staff for technical conference in each case. More than 10,000 present research projects of Federal and State agencies were thus reviewed.

The technical staff of the survey committee conferred also with several thousand industrial executives and research workers, in every State. Universal and cordial cooperation was encountered. As a result the Department of Agriculture has been made acquainted with a very large number of research projects which are being carried out in laboratories of endowed institutions, industrial companies, and under other private auspices. Although confidential information was not sought, it is believed that the survey staff has been able to gather material that gives a very comprehensive and complete picture of the general character of commercial work now in progress that is intended to establish new industrial activity for the utilization of agricultural commodities. The general nature of these projects will be summarized briefly in this section of the report. A classified and critical comprehensive summary is presented in part II.

RESEARCH SUGGESTIONS SOUGHT

The survey conferences and correspondence were not limited to research now actually in progress. Suggestions and recommendations for new investigations were also sought. In many cases these recommendations have been even more valuable in planning the Department's program for the new regional laboratories than the facts about present activities.

Furthermore, the survey of present research was extended to include work being done on all classes of agricultural commodities. This was desirable in order that each new project for the regional laboratories could be judged in relation to the whole problem, not merely to present studies on a single commodity. This breadth of viewpoint has made available many suggestions and much information regarding farm products not in surplus which are likely to be directly adaptable to the research plans for the surplus commodities.

The survey has included inquiries at more than 1,300 institutions, about 1,100 of them of industrial nature, some of which are doing scientific and engineering work with reference to industrial commodities that do not now have any relation to agriculture. The purpose of so extending the survey was to insure the best possible background in fields where agricultural materials may later be used. Experience has proved the value of that idea, for some of the most useful suggestions have come from institutions having little relationship either to present agricultural research or even to the projects planned for the new laboratories.

SURVEY RESULTS

The instructions of Congress with respect to the establishment of the regional laboratories make it clear that new and enlarged uses of agricultural materials will be the primary objective of all work. The survey has disclosed some present activity and many interesting opportunities for investigation of this sort. These are of widely varied character.

Perhaps the largest part of all of the research now being done under either Government or commercial auspices deals with the production and processing of agricultural materials with food products as the major objective. This is natural, since both plant crops and animals are raised mainly for food. Hundreds of such research projects described to the survey staff are so remotely related to industrialization as not to require detailed report at this time. Information of the nature was recorded, however, and it will be of value in further administration of Department work to which it relates in agencies other than the new regional laboratories.

Some hundreds of projects reported during the survey relate only to production phases of commodity problems. Many of these have to do with the breeding or selection of varieties of plants or animals which are most advantageous for development. Another great group of such investigations deals with cultural methods, fertilization, and other subjects within the broad field of agronomy. To a limited extent, all of these agricultural projects have a bearing on industrialization of the commodities produced, for very frequently it is necessary to select certain varieties or to follow certain cultural methods in order to get a commodity that is well suited to industrial processing. In

the several commodity sections of part II of this report will be found summaries of work of this sort which is pertinent to the present survey.

A third great group of agricultural research activities now in progress deals with the primary preparation of agricultural materials for market. In such cases as fruits and vegetables, for example, the goods must be washed or cleaned or chemically processed in order to be satisfactory for general marketing as fresh commodities. Research of this character disclosed by the survey is, in a number of cases, directly related to the problems which may be undertaken by the new laboratories. To that extent this type of investigations will be summarized and the significance in the planning of the regional laboratory program will be made clear.

Of much more direct importance for the new laboratories is the work being done at many commercial establishments on methods for processing of agricultural commodities. For example, numerous researches are under way on improved methods for the canning of fruits and vegetables or for the development of manufactured foods of other types. Outstanding among unsolved problems of this sort are the many projects associated with the recovery of byproducts or the utilization of wastes at present food-processing plants. Much further research is needed in those fields and considerable promise of further industrialization appears here.

Many recommendations made to the survey staff relate to new materials that might be recovered from agricultural commodities. Other recommendations deal with recognized needs for products for which present sources are not known. In a large number of other cases the problems of waste disposal are an outstanding feature of the suggestions regarding the most urgently needed research.

The relative importance of these various aspects of the problem differs greatly, according to the commodity under consideration. Part II of this report, which is presented by commodities, sets forth for each kind of commodity the interrelation of the various kinds of investigations. The experience of many persons with present research work and the many recommendations for new types of studies of each commodity, as they have been disclosed by the survey, provide an excellent foundation on which to establish the programs for the new regional laboratories.

The Department contemplates a continuance of its detailed study of this information during the coming year, while the new laboratory buildings are being erected. In fact, the first task of the new research staffs as they are selected will be an analysis of the many details disclosed by this survey. Thus every pertinent comment on any particular commodity will be taken into account before actual experimental work begins.

There will also be urgent need for extensive survey of the scientific and engineering literature in order that every item of present published knowledge may be taken into account as fully as possible. By this procedure the initial experimental and field studies may be advanced as rapidly as possible when the buildings and laboratory facilities are ready for use.

PROPOSED RESEARCH PROGRAM

Congress has determined that there shall be four regional laboratories, each dealing with surplus commodities of its region. It is evident, however, that a national outlook should be maintained at all times, even with respect to regional problems. The results in each laboratory will, of course, be made available to all parts of the country; and they will be applied as promptly as possible in whatever region and to whatever crop they may be found adapted.

There will be considerable variety in the investigations undertaken at the regional laboratories. In some cases it will be necessary first to make exploratory studies before detailed research can begin, especially in fields never before studied either by the Department of Agriculture or by other research institutions of the country. Because of the very far-reaching nature of the problems, many radical and novel investigations will be required. Not all of these can succeed. But it is believed that all will contribute to an understanding of what American industry can do in order to use profitably agricultural goods.

In many cases exploratory work has already been done on certain commodities, certain possible products, or certain new processes which look worthy of further investigation. In these cases, serious scientific research of an intensive and fundamental nature will be required. This can be undertaken at once. Not infrequently, work of the most abstruse and difficult scientific sort seems necessary. Here again, new sums of human knowledge will be forthcoming even when the immediate and hoped-for practical result may not always be reached at once.

Many of the investigations required are known to be of a sort that will take a number of years, perhaps very long periods, for complete solution. Such projects will be undertaken as a part of the regional laboratories program because they give, in the long range, great promise. It is recognized that in many cases only the Government might be looked to to finance and carry through studies of this sort.

When fundamental work has been done, there still remain laboratory research projects of an industrial or applied nature before engineering can begin. Some research of this kind can be initiated soon on the basis of published present knowledge. Other like projects will follow as the second stage after the fundamental pure science work of the new laboratories themselves.

A third class of research will be undertaken for the development toward practical application of some of the more promising present scientific knowledge. This engineering development on a pilot-plant scale will, it is hoped, give at an early date results on which industries may initiate new large-scale use of farm products. Effort will be made to press certain of these projects very aggressively so that practical benefits coming from each laboratory may not be unduly delayed.

It may not be practicable for the new laboratories to undertake all of the investigations of an engineering or developmental character that will be desired. Frequently, it is hoped, such investigations can be carried on with present industrial facilities. Thus, the funds provided for the regional laboratories can be conserved for such work as industry is not prepared to undertake. Furthermore, the results of such engineering development will be most promptly available and

most advantageously used for actual application in new processing on a commercial scale.

It is expected that the work of the new regional laboratories will be carried out on the same frank, open basis as has governed the previous research work of the Department. Close cooperation with States, educational institutions, and industry will be encouraged. Businessmen will be constantly urged to study the work being done and to utilize for public benefit the results being obtained. The Department will reserve the right of control of such developments only so far as it is necessary to insure the greatest promptness of commercialization and a fair development by all proper interests competent to serve the farm producers of raw materials and the general public who will be consumers of the products made.

Part III of this report presents a program of research dealing with the commodities or subjects that will be considered initially by the new regional laboratories and cooperating agencies. The presentation is necessarily in rather general terms. It is hoped, however, that it will give an understanding of certain major problems as the Department views them and of plans proposed for a useful national attack upon them. The principles which may guide the coordination of the work of the Department of Agriculture and other research agencies are considered in the introduction to part III.

The selection and organization of the scientific staff is only now under way; and the detailed analysis of survey results and of scientific literature, above referred to, remains to be made. Completion of these steps may make necessary certain modifications in the program as outlined in part III. The program as given is, however, a dependable outline of the type of work needed and the manner of approach the Department will follow in the work which it can undertake. It is presented to Congress at this time with only the necessary reservation that it must be regarded as preliminary and subject to modification in many details.

This reservation is even more true with respect to the laboratory program of the more distant future, for it is quite possible that events may prompt a gradual broadening of this work. The agricultural surplus problem is not static; it will undoubtedly take on many new forms as years go by. The initial work laid out for these laboratories, therefore, is not regarded as setting any outer limits to the future program. The expectation is that additional products will be studied and broader questions dealt with as time goes on. In other words, part III of this report is submitted essentially as a groundwork program upon which it will be possible to build in the future.

RELATION TO PRESENT RESEARCH

The experimental program for the new regional laboratories will represent an enlarged effort on problems on which a limited amount of work has been under way in the Department. Of the 10,000 projects of Federal or State agencies reviewed in the course of the survey, approximately 800 are somewhat related to the quality of raw materials or to their use in industry. Of these about 150 have been found to relate closely to questions of new industrial uses of agricultural materials. Some of these represent exploratory and others fundamental scientific work which will furnish an adequate basis for

new industrial or engineering development programs. Careful examination is being given to research work which has developed beyond the test-tube stage with the purpose of determining its value for inclusion in pilot-plant application. Where such advanced engineering and development work is needed, cooperation will be developed with the existing research agency to accomplish this purpose. In most cases, it is expected the work of the laboratories will relate to entirely new subjects.

The Department is making a careful analysis of the interrelationship between all new research and that already under way. Arrangement is being made to avoid duplication and to make each part of old and new research mutually helpful to all of the interested agencies. A further discussion of the principles of this coordination of effort will be found in the introduction to part III of this report.

As in the case of experimental work done under the Bankhead-Jones Act, all new projects of the regional laboratories will be organized to permit the fullest cooperation within the Department and with State and university activities. For example, the recent experience of the Bureau of Chemistry and Soils in establishing a regional soybean laboratory at Urbana, Ill., involving industrial cooperation problems, is proving very valuable in guiding these larger industrial research projects. In the soybean program arrangements were made for coordination within the Department and with all 12 States of the region in which related work was being done, and active and regular cooperation with the State agencies has resulted. Frequent meetings are held at which a number of specialists confer, both for the benefit of the Department staff and for exchange of information between other interested groups.

A like plan for coordination of the regional laboratory program is under consideration. In some cases it is expected that research being done by other laboratories may be taken into account in such a way that the complete program of study will really consist of the joint efforts of several active institutions. Collaborators will be named and advisory committees will serve actively. Thus the influence and constructive assistance of the regional laboratories may achieve maximum results for the benefit of all.

It is not contemplated that the new regional laboratories will themselves require an independent program for many of the agricultural research projects which are a vital part of a complete effort to secure commercialization of certain commodities. This is because the present work of the Department and of State experiment stations is often adequate with respect to genetics, agronomy, animal husbandry, and some other fields of scientific work which are essential prerequisites of chemical investigation and engineering development. The Department's facilities for coordination to this end seem adequate, and they will be utilized to the full, not only in formulating the initial program in detail, but also for its administration and amendment as experience may make necessary.

RELATION TO INDUSTRY

The ultimate objective of the work of the regional laboratories must be the increased industrial use of the products of agriculture. Every effort will therefore be made to have the scientific and engineering projects at the laboratories so organized as to be promptly

adaptable to the use of industry. As soon as any project matures to a point at which industrial development is justified, every facility of the laboratories will be afforded to industrial groups interested, so that they may put into practice the experimental findings at the earliest practicable date.

The fact that industrial research laboratories have been very generous in their cooperation during the survey indicates that continued cooperation will not be difficult. Many of the most helpful suggestions regarding new types of work have come from such sources. In not a few cases the Department has been urged to undertake investigation of what are now wastes or low-value products of present industry. The finding of methods for the profitable disposal of certain materials now wasted as an incident to the manufacture of canned, preserved, or processed foods is one of the important possibilities for new work. If such materials can be changed from nuisances or wastes into useful byproducts, the net cost of food manufacturing may be lowered and the spread in price now existing between the farm and the kitchen may be reduced.

Putting these agricultural wastes to some profitable use would naturally increase the gross return for the crop, absorb some of the overhead cost, and reduce the net cost of the food commodity itself. Industrial utilization not only would bear part of the cost of production of the entire crop and provide a means of raising the farmer's cash income, but at the same time would make possible a reduction in commodity cost which should be passed on to the consumer. Thus, with proper economic adjustment, it would benefit producer and consumer groups alike.

INTERCOMMODITY COMPETITION

It has been frequently emphasized by those consulted during the survey that the Department should undertake promptly studies of nonfood products which might be made from present food materials or from food-plant wastes. Such ventures if successful would, of course, greatly expand the total market for the products of agriculture and thus be much more advantageous for the farmers than development of new food products, which more often than not are merely substituted for present foods.

The development of new foods at these laboratories, therefore, will probably be a subordinate part of the entire program because of the limited advantage which can come to agriculture from mere change from one foodstuff to another. Interfood competition is so keen already that the new laboratories should not embark on that type of research, which would result largely in further food competition.

To a somewhat lesser degree the similar problems of competition between feeding stuffs will limit the work of the new laboratories. At the present time the largest proportion of many of the major cereal crops reaches the market only in the form of animals or animal products. It is not necessary, therefore, for these regional laboratories to consider industrialization of these goods in the form of new feeds, especially when the new product would merely displace one already serving satisfactorily. But this limitation does not extend to studies which may translate present industrial wastes or byproducts into satisfactory feeds. This latter type of activity will be constructive

and may result in important economic advances for agriculture as a whole.

In a few cases it appears that research may make new products available from agricultural materials that can replace commodities now developed from other sources. For example, certain plastic materials are now being made that can be used in place of metals. Such possibilities will be vigorously investigated in the new laboratories as affording the most advantageous type of commercial development.

Products of this kind have two major advantages to the public as a whole. In the first place, they utilize a replaceable material which can be supplied from the crops of the country. This may extend the life of some nonreplaceable natural resource correspondingly. In the second place, such applications of agricultural materials are often entirely new and furnish a regular new source of cash income to the farmer. They do not represent merely substitution of one agricultural material for another. In many cases they may not represent even the substitution of an agricultural material for any other sort of product, because the service rendered may be entirely new. Under such circumstances there are benefits to agriculture, which achieves a new market; to the public, which gets a new product; and to the industries and workers of the country, who have new business and new employment. Obviously developments of this character represent an ideal objective toward which the laboratories should work.

REPLACEMENT CROPS

During the survey of present research, recommendations regarding new types of investigations have been sought on every occasion, by correspondence and conference. Perhaps the most frequent recommendation made to the Department has been that work should be done in the new laboratories to encourage new or replacement crops which may be developed by agriculture. Such recommendation roots in the fact that a surplus may demonstrate itself most conspicuously by idle acres or idle farmers, and only to a small degree by actual excess of goods in granary or warehouse. To meet such surplus problems effectively the farmer must be provided with new types of crops to be grown, in order that he and his acres need not remain idle.

To a certain extent, it would be possible for the new regional laboratories to undertake that type of work, and numerous useful recommendations for specific projects of this nature have been received. However, the present law establishing the laboratories does not permit that any substantial part of the work of these new institutions should be so directed. Therefore the initial program for research does not embody any of the important suggestions regarding industrialization of possible new or substitute crops.

One or two examples will illustrate the type of research which might be undertaken. One of the outstanding problems which affect many important crops of the United States is the faulty distribution of the types of oilseeds or oil crops now available. This country produces large quantities of cottonseed oil. But we produce far less than we use of certain other types of oil, notably paint oils and soap oils. Two

of the most promising types of research that have been recommended to the Department would deal with these two kinds of materials. Some of this work can be done under the present authority of the Department. For example, it is proposed to investigate ways in which cottonseed oil and other surplus seed oils might be modified by chemical treatment so that they would be available and satisfactory for wider industrial usage.

At the present time, however, the research laboratories may not take up the corresponding problems of developing new seed-oil crops which would be directly applicable, as for example the growing of tung, safflower, castor-beans, or perilla or the other types of oil nuts and seeds of which domestic supplies are altogether inadequate.

LOCATIONS OF LABORATORIES

In order to carry out effectively the work of research, it is essential to have a building of adequate size and equipment of suitable variety. Research work requires also the stimulus of a proper environment and the encouragement of frequent and stimulating professional contacts. Moreover, there are a great many technologic considerations that determine the adequacy of a site or of the facilities available for a laboratory of the magnitude contemplated.

Recognizing these points as of very great importance for the future success of the regional laboratories, the Department surveyed the entire country with great care. More than 200 localities were carefully investigated, and about 80 of these were personally visited by Department inspectors. As a guide in determining the most advantageous locations the following criteria of a technical nature were considered:

A. *Accessibility.*

1. The degree of accessibility of the city or town itself by railway, highway, and air.
2. The relation of the city or town to important producing areas or points of concentration for the agricultural commodities common to the region.
3. The ease of access to related processing industries, particularly those that have been developing new processes and new materials by research methods.
4. The ease of access to the State agricultural experiment stations of the region in which the laboratory is located.
5. The ease of access to material supplies, service, trades, and equipment manufacturers.

B. *Housing and living conditions.*

1. Facilities which will make it possible to recruit and hold a high-grade staff of 200 to 250 people, with adequate housing and favorable living conditions for themselves and their families.

C. *Availability of a good site.*

1. The availability of a tract of land, at least 20 acres in area, properly located with respect to city development, public utilities, and housing, and suitable for a building site.

D. Essential services available at the site.

1. A pure and dependable water supply of at least 1,000 gallons per minute.
2. Sewer lines and sewage-disposal means capable of handling at least 1,000 gallons per minute of effluent possibly containing industrial wastes.
3. A gas line capable of supplying at least 3,000 cubic feet per hour.
4. An electric power line capable of supplying at least 1,000 kilowatts.

Analysis of all the information available, including much that was submitted by local organizations in the form of comprehensive briefs, resulted in a list of cities in each region which could be approved from this technologic viewpoint. Administrative review within the Department, taking into consideration broad matters of Department policy, then made the definite decision which placed the Eastern Laboratory in the Philadelphia area, the Northern Laboratory in Peoria, Ill., the Southern Laboratory in New Orleans, La., and the Western Laboratory in the San Francisco Bay area.

PLANS FOR IMMEDIATE WORK

The survey of present research and the study of suitable laboratory locations have required substantially all of the time available since Congress authorized the establishment of the regional laboratories and ordered the survey last June. Nevertheless, satisfactory progress has been made in the preparation of plans for the new buildings which will be required and in the selection and appointment of certain key members of the research staff for each of the four laboratories. It is anticipated that actual construction of the new buildings can be undertaken in the near future. The installation of scientific apparatus and the erection of engineering equipment for research will follow.

For the administration of this work, a new unit has been established in the Bureau of Chemistry and Soils, under an assistant chief of that Bureau, who will devote his entire time to these laboratories and the administration of the experimental work. Each laboratory will be headed by a director, who will be assisted by a group of major-project leaders. Each project leader will be a specialist, capable of directing in detail the varied types of research required within his division of the field. Studies indicate that from 5 to 10 such major-project leaders will be located at each laboratory. Under each will be a suitable staff of scientific, engineering, and other specialists, familiar with the problems to be investigated.

It is expected that within the next 3 or 4 months many of the major-project leaders can be engaged in order to begin promptly the further detailed planning of each research program. The preliminary investigation of present knowledge as disclosed in periodical literature and additional conferences with workers of the Government and industrial concerns will enable each leader to mature the preliminary programs here reported.

Most of this work can and should be done in advance of the completion of the laboratory buildings, some of it even in advance of the selection of junior members of the technical staff. The studies of the next 6 months should determine in many cases what sort of research is now possible, what methods will be used, and consequently what type of scientists will be engaged and what sort of laboratory facilities should be installed.

PART II. SURVEY REPORT

INTRODUCTION

This part of the report summarizes the results of the survey made by the Department of Agriculture of research now going on in the United States to find new or enlarged industrial uses for agricultural commodities. It gives also a summary of the suggestions made to the survey staff regarding additional investigations. This summary of present research and recommended investigations makes a fairly comprehensive picture of the ideas of those now active in this field in governmental, educational, and industrial research laboratories, as well as farm organizations. So in presenting its summary of present and recommended research the Department undertakes merely to hold up an undistorting mirror to reflect present activities and thinking.

To gather this information the Department organized a special staff of its own experienced personnel who visited each one of the principal laboratories where information on these subjects was obtainable. Approximately 1,300 institutions were visited, including about 1,100 industrial research laboratories.

The reception of the investigators was in most cases most cordial, and information was furnished generously. However, the Department instructed its field staff to avoid the acceptance of confidential information. This limitation was necessary in order that the work of the Department might not unreasonably embarrass present industrial groups who were willing to cooperate, but who could not be expected to furnish information about confidential projects in the preliminary stage.

It should be clearly understood that the summary in part II is not a recommended program of research formulated by the Department. Part II is just a condensed and systematic arrangement of the material gathered by the survey, and is not critically reviewed here from the point of view of either relative urgency or general importance. The program of research which will be undertaken by the Department at the new regional laboratories is outlined in part III.

It was disclosed by the survey that in many instances seemingly similar projects when carefully investigated involve either dissimilar methods or different objectives. For this reason it was not practical to summarize all of the information gathered with any indication of the source of the information. However, a list of institutions and organizations consulted during the survey is included as part IV of the report.

In its formulation of a compact summary of the many research items disclosed, the Department experienced some difficulty in determining whether or not certain projects are identical with others. It may be, therefore, that this part of the report will not completely disclose all of the details which specialists in various fields of research would like to have. For example, there may have been types of

research described to the survey investigators that are not adequately reported in this summary. But taken as a whole the summary does describe in a major way all of the important types of investigations discovered during the field work of the survey, which was confined to approximately 4 months and yet had to cover the entire United States.

The Department is expecting, as the work of the regional laboratories develops, to further amplify its study and to elaborate on many parts of this survey. Such further development will be a natural and necessary part of the planning of scientific and engineering work for each of the regional laboratories. The Department will also, on appropriate occasions, be glad to discuss with those interested other phases of the research here described that may not be included at first in the work of the new laboratories.

The statistical material in part II is based on statements and tabulations published by the Bureau of the Census and the Bureau of Foreign and Domestic Commerce, United States Department of Commerce, the Bureau of Agricultural Economics of the United States Department of Agriculture, the Giannini Foundation of the University of California, the National Cannery Association, and recent Yearbook and Statistical Numbers of the Western Canner and Packer. Maps and charts have been provided by the Bureau of Agricultural Economics. Detailed information not included in published statistics has been freely and gladly furnished by several of these agencies.

It will be noted that part II includes not only those commodities which can be given initial attention in the regional laboratories, but in addition all the other major commodities on which research was found to be in progress. It is hoped that this broad treatment of the subject will facilitate a review by others of their own research programs, and possibly encourage new research work on many commodities for which the Department may not be able initially to take up experimental studies.

LIST OF COMMODITIES

For convenience of presentation and clarity of understanding by those who use this report, various crops have been grouped together, and various other commodities of related type have been assembled according to the characteristics which make them important for further industrialization. It will be noted also that some sections relate not to agricultural commodities themselves, but rather to some important single constituent common to several commodities, such as starch, oil, or protein. The commodity sections are arranged in the following sequence:

Cereal crops:

Corn:

Starch and sugar.

Fermentations.

Motor fuels.

Wheat.

Barley.

Oats.

Minor grains.

Agricultural wastes.

Cotton and other fiber crops:

Cotton.

Cotton fiber:

Cotton lint.

Cotton linters.

Whole cotton.

Cellulose.

Flax (fiber).

Cotton and other fiber crops—Contd.	Root crops:
Hemp.	White potatoes.
Ramie.	Sweetpotatoes.
Broomcorn.	Other tuber crops.
Miscellaneous fiber plants.	Sugar crops:
Oil seeds and crops:	Sugar beets.
Seed oil research.	Sugarcane.
Cottonseed.	Sorgo.
Peanuts.	Maple products.
Flaxseed.	Honey.
Soybeans.	Other sugars.
Castor-beans.	Tobacco.
Tung nuts.	Forage crops:
Corn and wheat-germ oils.	Alfalfa.
Miscellaneous oil seeds.	Other hay and forage plants:
Fruits, vegetables, and nuts:	Clovers and timothy.
Tree fruits:	Cowpeas.
Tropical and semitropical	Soybeans for hay and forage.
fruits:	Lespedezas.
Citrus fruits.	Velvetbeans.
Avocados.	Forest products.
Dates.	Naval stores (turpentine and rosin).
Figs.	Vegetable tanning materials.
Olives.	Speciality crops:
Papaya.	Drug and other special plants.
Deciduous fruits:	Hops.
Apples.	Dairy products: Proteins.
Pears.	Poultry and eggs.
Stone fruits:	Meat and meat products.
Peaches and apricots.	Animal fibers for spinning:
Cherries.	Wool.
Plums and prunes.	Mohair.
Small fruits:	Silk.
Grapes and raisins.	Hides and skins.
Berries.	Fur animals.
Melons.	
Vegetables: Pickling crops.	
Edible tree nuts.	
Processing wastes.	

COMMODITY REPORTS

CEREAL CROPS

In this report the current and suggested research dealing with cereal crops is summarized under "Corn, Wheat, Barley, and Oats," while in the section "Minor grains" is grouped research pertaining to buckwheat, millet, rice, rye, and sorghum.

These crops may be considered as being essentially starch crops, although they also yield substantial quantities of protein and oil as well as tremendous tonnages of fibrous materials, such as straw, stalks, hulls, and cobs. For this reason all current and suggested research related to starch has been assembled in this section. Because corn is the most important domestic raw material for the production of starch, this research has been treated in the section "Corn." Fuels derived from farm products, and all pertinent work on fermentation, are also discussed under "Corn" because of their close relationship to starch and corn utilization. Discussion of research on agricultural wastes will be found in a separate section bearing that title.

Because of the similarity in chemical composition and the many interrelated problems connected with their utilization, it is suggested

that the most complete picture of current and suggested research for any one of the cereal crops can best be obtained by reading the entire section dealing with this group of commodities.

CORN

Three distinctly different types of corn—sweet corn, popcorn, and field corn—are cultivated in the United States. Popcorn is a specialty crop grown in very limited amounts and sold entirely for use as a confection. Sweet corn, which enters the fresh-vegetable market and is grown in fairly large acreages for canning, is discussed under the heading "Vegetables." The following considerations of corn as a commodity are limited to field corn, which constitutes one of the major agricultural crops in the United States.

World production of corn has remained practically constant at 4 billion bushels since 1900. Of this, the United States produced about 68 percent prior to the World War, and about 60 percent in recent years. The Corn Belt, so-called, is the center of production, and consists of a broad belt from Nebraska eastward to central Ohio. However, corn is also the most important grain throughout the South, equaling cotton acreage in several Cotton Belt States. For many years the United States has grown about 100 million acres of corn each year. In the last few years, however, this acreage has dropped to about 94 million. The domestic corn crop usually has ranged from about 2.5 to 3 billion bushels, the average yield per acre being in the neighborhood of 24 to 28 bushels for the country as a whole. In recent years the amounts of corn ordinarily carried over from one year to another, that is, stocks on farms on July 1, have averaged about 400 million bushels. At the same time, commercial stocks of corn in trade channels on July 1 have amounted to from 7 to 48 million bushels. The bulk of the corn crop moves to market in the 3 or 4 months following harvest. January and February are the months of peak receipts at primary markets. Chicago is by far the leading receiving center. It is followed in order of importance by St. Louis, Omaha, and Kansas City.

Although the major portion (about 90 percent) of the corn crop is utilized for animal feeding on the farms where it is grown, that portion of the crop which has been sold has brought farmers a cash income of about 250 million dollars for each of the past 2 years. Corn prices, however, react sensitively to supply. There is also a very close relationship between price of hogs and price of corn, inasmuch as an important proportion of the crop is employed as feed for hogs. Corn prices reached a high point during the war, fell precipitately in 1920 and 1921, recovered somewhat in the next 2 or 3 years, but have been relatively low most of the time since 1926. Notwithstanding that acreage has been reduced in the last 3 or 4 years, low corn prices have been very disturbing to the economy of Corn Belt agriculture. The corn situation in the fall of 1938 illustrates fairly well the development at times of a rather serious surplus problem. With corn supplies above average and livestock numbers below average, corn prices declined considerably during 1938, the average price of No. 3 yellow corn at Chicago for October being 44.7 cents a bushel, or the lowest monthly average since November 1933. The average for November 1938, however, was somewhat higher, being 46 cents.

The average disposal of the corn crop is as follows: Feeding hogs, 39.7 percent; feeding cattle and sheep, 24.5 percent; feeding horses and mules, 13.7 percent; other farm uses, 12.8 percent; and industrial and city uses, 9.3 percent. In recent years, the quantity of corn fed to cattle has increased somewhat, but this increase has been much more than offset by the decrease in the quantities of corn fed to horses, mules, and livestock not on farms. The replacement of power animals by motor power has decreased the demand for corn by about 4 percent of the total crop. Exportation of corn from the United States has been large in only a very few years. Record exports occurred in the year beginning October 1, 1921, when 168 million bushels were exported, or 5.7 percent of production. The following year exports amounted to 64 million bushels, after which they declined to an average of 6 million bushels during the 5-year period 1929-33. During the drought years 1934 to 1936 an average of 54 million bushels was imported. Then following the very small crop in Argentina, the United States exported 138 million bushels during the year beginning October 1, 1937, which was 5.2 percent of production and second only to 1921.

In discussing the processing of corn, there is some question as to how the term "industrial utilization" may be defined. Using the term in its broadest sense as being applicable to that portion of the corn crop which enters processing industries, the amount used industrially is about 9 percent of the total crop. Of this percentage about one-fourth is returned to the farmer in the form of byproduct feeds and one-half enters the food market. In other words, the actual percentage of the total corn crop which enters nonfood uses is very small. However, many of the edible corn products enter noncompetitive food markets, which is a distinct advantage so far as the American farmer is concerned.

Industrial products made from corn are largely starch and starch derivatives because starch makes up approximately 60 percent of typical corn kernels. The primary objective of both dry milling and wet milling of corn is to separate the endosperm, or starch-containing portion, from the hull or bran, and the germ, which is the oil-bearing portion of the kernel. Both endosperm and germ contain protein.

The dry-milling industry makes a physical separation of the dry-corn kernel into the endosperm, the bran, and the germ. The endosperm, or starchy portion of the kernel, is further milled to yield hominy and grits, corn meals of various types, corn flours, processed flours, flaked products, and prepared cereal foods; and the largest part of the income of this industry is derived from the sale of these and related food products. The germ is pressed for corn oil; the resulting germ cake is ground to a coarse meal, and with the bran and wastes from milling is sold as stock feed. Most of these products are used as foods but there are also many nonfood uses, such as artificial snow for the movies, cold-water paints, cold-water pastes, foundry flours, and fillers or sizing products.

In the wet-milling industry the corn is steeped, then separated into starch, gluten, germ, and bran. As in the dry-milling industry, the germ is pressed for corn oil and the press cake, together with all other byproducts, is returned to the feed market. The starch, which is the primary product, is further processed to yield modified starches, dextrans, gums, sirups, and crude and purified dextrose or corn sugar.

These products are utilized in various food products such as corn-starch puddings, caramel coloring, ice-cream powders, jams, jellies, baked goods, and confectionery, and in the brewing industry. They also find an outlet in such nonfood products as laundry starch, paper and textile sizes, explosives, adhesives, and colors. Further, they are employed in the tanning of leather, in rayon manufacture, and in the production of mannitol, sorbitol, and fermentation products. The starch is separated from the gluten by washing and sedimentation. The wash waters are concentrated to recover the gluten, which is utilized as a high-protein component of feeds.

Thus far wet-milling methods have developed more industrially useful materials than the dry-milling methods. Wet-process grindings of corn for the production of starch and allied products have ranged during the past 10 years from a low of 55 million bushels in the season 1934-35 to a high of 88 million bushels in the season 1927-28. A typical picture of the output of industrial derivatives by the wet-process industries is given for the year 1937. The sales of products in that year were:

	<i>Million pounds</i>
Cornstarch.....	731
Corn sugar.....	418
Corn sirup.....	1, 035
Dextrins.....	83
Crude corn oil.....	20
Refined corn oil.....	113

To these might be added:

	<i>Million pounds</i>
Gluten feed and meal.....	1, 084
Corn-oil meal.....	58

Any significant expansion of the industrial utilization of corn must depend basically on the development of new or more extended uses for starch or products derived from it. Such expansion may take place under one or more of four types of processing industries, namely, dry milling, wet milling, fermentation for industrial chemical products, and fermentation for the production of motor fuel. Of these, wet-milling methods offer the most promise for future expansion. Preparation of chemicals from corn by specialized types of fermentation appears less promising than fermentation for motor fuel, primarily because of the magnitude of the potential market for alcohol as a motor fuel if its use becomes economically feasible. In research on corn products, the competitive relation of corn to other agricultural raw materials must be considered, as well as the competition of these agricultural products with those secured by the methods of synthetic chemical manufacture using raw materials which do not come from agriculture.

The competitive position of corn will illustrate the complexity of the economic-technologic problems which must be faced in determining any research program. While the starches isolated from different plants (cornstarch, potato starch, wheat starch, rice starch, tapioca, etc.) differ in physical properties, they are fundamentally of the same chemical constitution. With minor exceptions, it is possible to modify each starch to such an extent that it acquires the physical properties desired for a particular use. Price alone determines the market outlets for the different starches except for a limited number of special

uses. The adhesive on postage stamps is an exception of this type, tapioca and sweetpotato starches having advantages over all others. For use in certain rubber products, cornstarch has the advantage. Potato starch is used in Germany in the same products for which cornstarch is used in this country, entirely because of agricultural price relationship.

The United States now imports considerable quantities of tapioca and sago, which, in the form of starch, can be and are substituted for starch made from corn. It is desirable that research be conducted in order to determine whether, by reducing costs of production or by improving quality, a larger part of our requirements for starch and allied products might be supplied by products made from domestic corn.

No adequate method of evaluating the possible increase in markets for starch and its derivatives is available. The statement is frequently made by technical men in the industry that the present markets for wet-milled products of corn could be doubled in 5 years. This increase would be primarily an expansion of present markets and does not depend upon the replacement of other domestic agricultural crops or the discovery of new uses.

PRESENT RESEARCH

Present research on corn is quite varied in character and in objectives. The survey has revealed that the research of the processing companies is devoted primarily to improving yield and quality, and to diversification of products derived from corn, with the objective of reducing costs and increasing sales outlets. Research in the State agricultural experiment stations and some bureaus of the Department of Agriculture is directed chiefly toward the solution of the farm problems of production and feeding of corn, although some investigations dealing with various aspects of utilization are also under way. In a few individual laboratories some work is in progress on the fundamental chemical and physical properties of the starch, protein, and fat constituents of the kernel.

Information collected in the survey has been classified under the following headings: Agricultural Research; Dry-Milling Process; Wet-Milling Process; Fundamental Research on Starch and Sugars; Fermentation; Saccharification; Motor Fuels; and Byproducts and Wastes.

Agricultural research.

1. Genetic studies on corn are directed toward the isolation of inbred lines and resynthesis of hybrids characterized by disease and insect resistance, adjustment to environmental conditions, stiffness of stalk, large root systems and other factors contributing to yield and quality of crop. Application of this type of research to synthesis of hybrids with qualities for particular processing purposes has been limited mostly to sweet corn and popcorn, to white corn for dry milling, or to abnormal protein and fat level in field corn.

2. Agronomic studies on corn are in progress at most of the agricultural experiment stations. These studies have for their purpose the determination of the effect of type of soil, climatic factors, cultural methods, and other variables upon insect infestation, yield, and quality of crop.

3. Scattered research is being performed on the variation in the constituent vitamins, pigments, carbohydrates, proteins, fatty oils, odoriferous principles, and enzymes of corn as a result of genetic or agronomic practices.

4. Research on harvesting, drying, and storing of corn is prosecuted to preserve the quality of the product and to decrease losses from storage diseases, insects, and other pests.

5. Extensive feeding studies of the entire corn plant and the whole grain are being conducted, since corn is the basic constituent of most concentrated feeding rations in the Central States. Use of the essential amino acids and fractions of the kernel produced as byproducts of the various processing industries is also being studied from the nutritional standpoint.

Dry-milling process.

6. Yield, quality, and diversification of products of the dry-milling industry are continuously under investigation, but this is done mostly by the operating personnel of the plant rather than by a special research staff.

7. Manufacture of nonfood products such as artificial snow, foundry flours or core binders, cold-water pastes, fillers, and sizing agents is the result of joint experimental efforts of producers and consumers of these products.

Wet-milling process.

8. Technologic manipulations involved in the process of extracting starch from corn are being studied. Work is constantly under way directed toward the improvement of quality and yield. Such work is generally carried out by the operating personnel.

9. Specialty products: A large number of modified starches, dextrins, and gums are produced in which the physical properties of each product have been carefully modified and adapted to meet the needs of specific consumers. The complex dynamic equilibrium with water, the complicated molecular structures, and in many cases the colloidal state of the products, have militated against the establishment of adequate scientific explanations of the various changes involved. As a result, each industry has developed and is continuously experimenting with a series of complicated arbitrary control methods which, as a rule, have little significance outside its own laboratory. Each producer maintains an active research program on production and marketing problems.

10. Saccharine products: Much research on the production, quality, and preservation of crude glucose, glucose sirups, and crystalline dextrose is being performed. Manufacture of crude glucose and glucose sirups dates back well into the last century, whereas the production of crystalline dextrose, which is one of the cheapest of pure organic compounds made on a large scale, is a recent development. There is a great deal of research on the use of these substances in such food products as baked goods, ice-cream mixes, canned fruits and vegetables, jams, jellies, beverages, caramel colors, sauces, confectionery, processed meats, vinegar, etc. Nonfood outlets have been developed in tanning, rayon, tobacco, and pharmaceutical industries. Research on mannitol, sorbitol, gluconic acid, alkylated and acylated glucose offers encouragement for expansion of nonfood outlets. The biological utilization of glucose as a raw material is discussed in the section on Fermentation.

Fundamental research on starch and sugars.

Starch, modified starches, glucose, fructose, sucrose, xylose, mannose, maltose, etc., which are sugars or sugar derivatives, are treated in this section. Glucose, a relatively simple organic compound, is the most common structural unit occurring in the plant world. Practically always it is found in a combined, condensed form as starch, cellulose, or sucrose (cane or beet sugar). A molecule of starch is considered to consist of several score or more units of glucose, and to have a globular shape. The arrangement of these units and the molecular form confer on starch the properties peculiar to it. Mild, graded hydrolysis or various heat treatments of starch yield the modified starches and dextrans which have characteristic properties and possess roughly a score or more of glucose units. By appropriate acid treatment starch can be converted economically and almost quantitatively to glucose. This reaction forms the basis of the modern "crystalline dextrose" industry, which has resulted in tremendous expansion in the amount of starch employed industrially. The analogous process of converting cellulose (in wood) to glucose sirup has assumed considerable importance in Germany's "Ersatz" campaign, this wood sugar being used either as a nonprotein cattle food or to produce a protein cattle food in the form of yeast, cultured on the wood sugar. Sucrose is widely distributed in nature, occurring in relatively large percentage in sugarcane, sugar beets, and some fruits. It is a combination product containing one molecule of glucose and one molecule of fructose. By suitable catalytic treatment sucrose can be hydrolyzed to its constituents, which in the mixed form are known as invert sugar. One other large source of fructose is honey, in which it occurs in the free form. Of the other simple sugars, xylose is the most abundant, being present in combined form as hemicellulose which occurs in all plants to the extent of about 25 percent.

Starch and sugars.

Fundamental research on starch is limited and is being done mostly in university and Government laboratories. Although present work is of high quality, progress has been slow due to the complexity of the problem and the widely separated locations of the groups engaged in this work, with resulting lack of coordination of effort.

Fundamental research on sucrose, glucose, fructose, xylose, and other sugars is treated in this section because of the similarity of the physical and chemical methods for dealing with them. In this country few men are devoting their efforts to research or teaching in the fundamental chemistry of the various carbohydrates. To encourage development in these fields the research activities at several institutions are subsidized by the corn processing industry.

Present fundamental research on starch and sugars may be classified as follows:

11. Genetic and environmental factors in relation to differences in the quantity and quality of starch produced by plants: Microscopic, fluorescent, and X-ray studies on the structure of starch granules and retrograded starches.

12. Physical studies of starch: Infrared absorption spectra; ultracentrifuge sedimentation; viscosity phenomena; osmotic pressure measurements; colloidal properties of starch pastes, changes in colloidal properties caused by various reagents; and quantitative evaluation of gel strength, viscosity, elasticity, etc.

13. Chemical studies of starch including fractionation of starch by various means and comparison of the properties of the different fractions; structural investigations of the starch molecule by various techniques such as methylation, esterification, oxidative degradation, and enzymic hydrolysis; and physical and chemical significance of trace constituents, such as the various metallic ions, phosphoric acid, and fatty acids in starch.

14. Hydrolytic changes of starch: Modifications of starch by physical, chemical, or enzymic techniques.

15. Physical studies of sugars: Relation between optical rotatory power and structure; crystallographic and X-ray data and their interpretation; mutarotation of simple sugars in various solutions; and attempts to elucidate the mechanism of mutarotation in its relation to structure.

16. Chemical studies on sugars: Analysis of complex mixtures of sugars by methylation technique and subsequent distillation; comparison of reactivities of hydroxyl groups and oxygen bonds in the sugars by speeds of reactions, labeling with heavy hydrogen, or absorption spectra technique; application to the sugars of typical organic chemical reactions, such as oxidation, hydrogenation, dehydration, alkaline degradation, acylation, methylation, and mercaptal and carbonyl condensation, to extend the information available on structures and reactions in the sugar series.

17. Metabolic investigation of biologically catalyzed reactions of the sugars; synthesis of sugar phosphates and enzymic degradation products to serve as a foundation for the biochemistry of the carbohydrates; and studies on the nutritional value of different sugars.

Fermentation, general.

The fermentation industries may use ground corn, dry-milled corn products, or wet-milled corn products. In most cases these corn products are in direct competition with blackstrap or invert molasses for the fermentation market. Since blackstrap molasses is a waste product of the sugar industry, it is always sold at a price slightly under that of an equivalent quantity of corn. As a result, the outlet for corn products as raw materials in fermentation has been restricted to the production of materials of high quality such as alcoholic beverages, vinegar, lactic acid, citric acid, and gluconic acid.

A general conception of the magnitude of the fermentation industries consuming agricultural raw materials is given by the production figures for their products, exclusive of food products. In 1936 more than 179 million gallons of wine, 245 million gallons of whiskey, and 1,600 million gallons of malt beverages were produced in the United States. During the same year production of industrial (ethyl) alcohol by fermentation amounted to about 187 million proof gallons, of which 169 million were derived from molasses and 18 million from grain. Some recent statistics on the production of miscellaneous industrial chemicals by fermentation are as follows: Citric acid, more than 10 million pounds in 1935 (latest available figures); lactic acid, more than 900 thousand pounds for food use in 1937 (production figures for nonfood uses not available); gluconic acid, 500 thousand pounds (estimated for 1937). Other chemicals produced extensively, but not exclusively, by fermentation processes include: Acetone, more than 124 million pounds (1937); butanol, more than 124 million pounds (1937); and acetic acid, more than 101 million pounds (1935).

Research work on yeast fermentation has been carried on for many years. Most of it has been directed toward the discovery of new and specific strains, the development of pure cultures, or the application of known yeasts to various mashes or worts. Several organizations in the United States are at present working on bacterial and mold fermentations. Some investigators are studying different micro-organisms on restricted types of nutrient solution, while others are studying varieties of substrates for growing specific organisms.

While some fundamental studies in progress deal with the morphology and physiology of micro-organisms, most of such research is directed toward the solution of problems connected with the identification and behavior of specific pathogenic organisms. Little co-ordinated effort is being made to extend such studies to improve industrial fermentations or to develop new processes.

Considerable research is under way dealing with specific fermentation problems connected with the processing of fruits, vegetables, and dairy products, ensiling of various green feeds and feeding byproducts, flax retting, curing of tobacco, composting, and other utilization of agricultural waste materials, and the treatment of hides and skins. Such current investigations will be found listed under other pertinent subjects in this report and will not be discussed further here. Information collected in the survey of current research in the general field of fermentation is classified under these headings: Yeast Fermentation, Mold Fermentation, and Bacterial Fermentation.

18. *Yeast Fermentation.*

(1) Production of yeast: Current research on the production of yeast includes studies involving a number of factors, such as: Nutrients; strain and age of yeast; seeding rate; temperature; pH; the quantities of bios, oxygen, alcohol, and carbon dioxide present in the fermenting medium; and other variables.

(2) Beverages: Breweries and distilleries use yeast in the manufacture of alcoholic beverages. Their research is being directed toward increasing the quantity of alcohol obtained from a given amount of raw material; and improving quality, flavor, or bouquet of their products.

(3) Industrial alcohol: Yeast fermentation researches that concern the manufacture of industrial alcohol are closely associated with, or parallel to, those relating to the production of alcoholic beverages.

(4) Glycerol: In most yeast fermentation processes small quantities of glycerol are formed, and some research is under way on economic methods for its recovery and purification from residues after removal of alcohol. Some desultory development research is being carried out on alcoholic yeast fermentations in the presence of sulfite or alkali to augment the formation of glycerol. Such processes have been known since the time of the World War, and receive renewed attention whenever prices of glycerol tend to rise.

19. *Mold Fermentation.*

(1) Exploratory surveys: Limited studies on the action of various molds on carbohydrates are under way. These investigations have for their objective the isolation and identification of the products of fermentation to determine if any might have industrial significance. Fundamental studies of the mechanism of some of these biological conversions are in progress.

(2) Production of organic compounds: Research on production of organic compounds by mold fermentation is yielding fruitful results. Operations involving the growing of the molds on the surface of substrates and in the submerged state have been successfully carried out. Further research is in progress on the effects of nutrients, accessory metabolic agents, pressure, time, temperature, pH, aeration, form of inoculum, and other factors on the fermentation process to determine optimum conditions. The success of some mold fermentation processes was made possible by the development of special equipment.

Production of gluconic acid from corn sugar is now a well-established industrial fermentation process. The acid, in the form of its calcium salt, is used principally as a pharmaceutical. Present research is directed toward the development of a continuous process for the production of gluconic acid by submerged mold fermentation under pressure, which may reduce the cost of production and therefore result in a wider market for the acid as a raw material. Production of dextro-lactic acid from dextrose (corn sugar) by submerged mold growths has several industrial advantages, chief of which are ease of recovery from the fermented liquors and purity of the end product. Studies are now being directed toward translating small-scale laboratory work to semiplant scale operations.

20. *Bacterial fermentation.*

(1) Fundamental researches including searches for industrially useful bacteria; studies on the physiology and growth of bacteria; examination of the end products produced by bacteria; and the commercial application of bacterial fermentation processes for the production of organic compounds. Among the end products of particular significance at the present time are propionic, butyric, and dextro-lactic acids.

(2) Studies on the utilization of acetic-acid bacteria. These organisms are capable of effecting the transformation of a large number of organic compounds, particularly polyhydric alcohols and hydroxy acids, to compounds of potential industrial value. Recent work has shown that these organisms are used for the industrial conversion of d-sorbitol to l-sorbose, which is a raw material for the commercial production of synthetic vitamin C (ascorbic acid). Studies are now in progress for the development of methods for producing rare and useful organic compounds by the oxidative action of micro-organisms of the genus *Acetobacter* when grown on various substrates, most of which are of agricultural origin. Investigations are also being made on the production of a 5-keto gluconic acid from dextrose, and of dihydroxyacetone from glycerol, by submerged growths of *Acetobacter suboxydans*.

(3) The butanol-acetone fermentation. This is one of the most important industrial fermentations and a great deal of research has been carried out on the process. Further studies are being made, however, for the purpose of developing conditions for the maximum production of solvents from various agricultural materials such as corn, grain sorghum, blackstrap molasses, and other carbohydrate materials.

Saccharification.

Many organisms, of which yeasts are the most important industrially, are incapable of using starch as such. In the production of distilled liquors, malt beverages, and industrial alcohol from grain, it

is necessary to convert starch to fermentable sugars such as maltose and dextrose. This process is known as saccharification. For this purpose malt, usually derived from barley, is used almost exclusively.

21. Malt extracts of high diastatic power are being developed and find a place in starch conversion. The development of malts from grains other than barley is also being studied and, so far, work on wheat and rye shows considerable promise. Barley malt has been used for conversion of starch into fermentable sugars by brewers and distillers for many years. (A review of the research on barley malt will be found in the section on Barley, p. 43.)

22. Use of molds for converting various starches into fermentable material is receiving consideration, especially for the manufacture of nonpotable alcohol. Various byproducts of the milling industries are being studied to determine their suitability as materials on which to grow these molds. Various brans show the greatest promise.

23. Acid conversion of starches to sugars is an industrial practice; however, the use of acids to convert starches for a fermentation process has never been practicable. Further studies are being made on this conversion process to determine its value in industrial fermentation processes.

Motor fuels.

The economic production of liquid fuels from farm products or from wood and the successful use of such derived products as ingredients of blended motor fuel are highly desirable as a means of aiding agriculture and conserving petroleum resources. However, many technical, engineering, and legal problems are involved. Recognition should be given to the fact that irreplaceable petroleum resources are being depleted at a rapid rate, with eventual approach of scarcity and higher prices for gasoline. Sources of replacement fuels should be explored now to assure continued supply, even though the engine of the future may differ in design and in fuel requirements from the present types.

The present annual consumption of gasoline as motor fuel in the United States is around 22 billion gallons, requiring about a billion barrels (of 42 gallons) of crude petroleum as raw material. A 10-percent alcohol blend would, therefore, require over 2 billion gallons of alcohol on a national-use basis. The total present fermentation-alcohol production capacity of the United States is only about 600 million gallons annually, divided almost equally between industrial-alcohol plants and beverage-spirit (whisky, gin, rum, etc.) plants. Perhaps half of this total capacity might be available for motor-fuel-spirit production, due to limitation of present markets for alcohol and spirits. In case of war or other exceptional conditions, there would probably be no excess capacity.

Current research dealing with the production of motor fuels from agricultural raw materials may be grouped as follows:

24. A comprehensive technical and economic survey of the factors involved in the production of power alcohol by fermentation. This survey includes studies of: Various raw materials as possible sources of power alcohol; present conventional fermentation methods and operations, as well as the costs involved; present uses and possible development of new uses for byproducts and wastes of power-alcohol manufacture; and the literature describing the utilization of alcohol and alcohol-gasoline blends as motor fuel. Preliminary studies with

respect to designing plants for the manufacture of power alcohol indicate the possibility of some departures from the conventional methods of alcohol manufacture.

25. Production of alcohol fuels from such raw materials as corn, grain sorghum, potatoes, and molasses by research organizations. The scope of the study as a whole has been somewhat limited due to inadequate financial support or lack of personnel.

Byproducts and wastes.

Agricultural byproducts and wastes of corn production, namely, cornstalks and corncobs, are discussed under Agricultural Wastes (p. 50). Corn oil, which is an important byproduct of both the wet and dry milling industries, is discussed in the section on Corn and Wheat-germ Oils (p. 147). Other research comprises the following:

26. Use of steep waters from the wet-milling process as a source of biological growth stimulants and as a source of inositol.

27. Production of protein fractions, including partially hydrolyzed proteins and purified amino acids, as byproducts of the wet milling of corn. These byproducts are finding outlets in coated papers and plastics.

28. Uses of byproducts of brewing and distillation industries. Considerable study is now being undertaken to extend the use of dry ice (solid carbon dioxide) in the refrigeration industry. Utilization of brewers' and distillers' grains, as well as distillery slop, for feeding cattle and hogs has been practiced for some time. Research is in progress to develop industrially useful products from these materials.

29. Use of mycelia and other substances recovered from mold fermentations as sources of accessory growth factors. Studies now in progress on the toxicity, metabolism, and nutritive value of mold mycelia may furnish valuable information concerning their possible use as raw materials.

30. Use of corn meal and ground cobs as carriers in poisoned baits for insects.

SUGGESTED RESEARCH

Research on corn which has been suggested during the course of the survey is presented as follows:

Corn as a raw material.

1. Genetic, agronomic, and pathologic research: Studies now in progress on corn as an agricultural crop should be extended to cover the individual constituents of the kernel. This research necessitates the development of a methodology for characterizing starch, fatty oils, proteins, pigments, enzymes, etc., which make up the kernel. Complete information is needed on: The composition of the germ, hull, and endosperm; the relative proportion of each constituent in the grain; the variations between inbred lines, crosses, and strains of corn; and changes in composition with maturity, season, harvesting, drying, storage, weathering, and diseased condition.

2. Grading corn: Present methods should be investigated from an industrial-utilization viewpoint.

3. Drying corn: Methods of artificial drying of corn for industrial purposes should have special study. The present methods of artificial drying are reported to disintegrate the flinty starch to a greater extent than does field drying.

4. Feeding studies on corn: These should be extended to include: The fractionated germ, bran, and endosperm; the individual proteins which are present in the germ and in the endosperm; physical modifications of corn gluten resulting from variations in processing; distillers' slops; and fractionated distillers' slops. The purpose of these studies would be to establish a basis for evaluating individual constituents of corn as feeds, and a guide for more intelligent utilization or preparation in industry.

Survey of literature.

5. A complete critical summary should be made of all published technical information relating to: Chemical composition of the corn kernel; chemical and physical properties of starch, protein, oil, pigments, enzymes, etc., found in corn; and patented and other processes for utilizing corn or corn derivatives. Existing bibliographies are either very limited in scope or are merely indexes to the literature by title only.

Dry-milling process.

6. Design and use of laboratory equipment for the study of dry-milling problems is essential: This research program should include all phases of tempering, degermination, gradual reduction, screening, bolting, and processing of corn on hot or cold rolls.

7. Physical, chemical, and biological changes accompanying the milling operations should be determined and quantitative techniques designed for their evaluation and control in plant operation.

8. Milling qualities of corn: This study should be made in conjunction with the genetic and agronomic programs of agricultural experiment stations.

9. Amylolytic and antioxidant enzymes in corn: These should be studied in conjunction with their significance in the utilization of the milled products.

10. Physical and chemical properties of products: The essential properties involved in the present uses of the various products and byproducts should be studied quantitatively with the object of extending present outlets and developing new outlets in foods, cleaning compounds, dusting agents, fillers, sizes, cold-water pastes and other adhesives, cold-water paints, and foundry binders. Methods of handling, utilization, and preservation should be included in the study.

Wet-milling process.

11. Laboratory or small-scale equipment should be designed and used to duplicate the various steps involved in the wet processing of corn. This research should include: (1) All phases of steeping, degerminating, grinding, screening, and bolting and the various operations of separating starch from gluten; (2) quantitative study of physical, chemical, and biological changes accompanying the various operations; (3) study of biological control agents other than sulfur dioxide; and (4) investigation of means for producing sterile starch.

Fundamental research on starch and sugars.

According to suggestions made by those interested in this phase of research on corn, the program should include:

12. Physical studies on starch, such as: (1) Variation in starches as a result of genetic, agronomic, or pathologic factors; (2) deposition

of starch granules in growing corn; (3) physical structure of the starch granule; (4) physical relation of the granules to the kernel matrix; (5) colloidal properties of the organized and disorganized starch granules; (6) preparation of starches from different species of plants, and comparison of their properties; (7) determination of the causes of physical differences among starches; and (8) application of ultra-centrifuge, ultra-filtration, diffusion, X-ray, spectroscopic, and other physical methods to starch for information on size and structure of the starch molecule.

13. Chemical studies on starch, such as polymerization by means of chemical agents, methylation, esterification, oxidation, hydrolysis, pyrolysis, etc.: Many of these reactions will yield information on the size and structure of the starch molecule. The role played by trace constituents should be determined.

14. Preparation of modified starches, dextrines, and gums by enzymic, chemical, or physical treatment of the various starches.

15. Physical studies on sugars: Studies should be made on the physical properties of: (1) Sucrose; (2) the various crystalline forms of dextrose, fructose, and xylose; and (3) solutions of mixtures of the sugars. Physical methods for the identification of sugars in mixtures should be developed. Application of spectroscopic, X-ray, polarigraphic, and other physical techniques is also needed to acquire information on the structure of sugar molecules.

16. Chemical studies on sugars: They should include: (1) Preparation of derivatives of sugars by graded methylation, acetylation, ammoniation, alkaline and acid degradation, polymerization, and halogenation with the object of utilizing such products commercially; (2) fundamental studies on the chemistry of the sugar alcohols looking toward improvements in chemical methods of producing sorbitol, mannitol, and ascorbic acid; (3) study of graded alkaline or acidic oxidation of sugars as a possible means for producing useful industrial materials; and (4) development of efficient methods for producing dibasic acids from sugars.

Fermentation.

Many chemical compounds have been isolated and identified as the products of metabolism of both molds and bacteria grown on various substrates. Suggestions for further fermentation investigations are as follows:

17. Biochemistry of micro-organisms: A systematic study should be made of this subject with a view toward the production of new and useful chemicals from farm materials. Such a study would include: (1) A search for new industrially useful organisms, necessitating the procurement and maintenance of a collection of all available microbiological agents and their frequent subculture, on suitable media and under favorable conditions, in order that the desired enzymatic activities may be preserved; (2) a survey of the microbiological activities of organisms, with special attention to the effects of nutritional and environmental variations including changes brought about by X-rays, on their metabolic products; and (3) determination of the optimal conditions for the production of maximum yields of desired products in the shortest possible time. Among the important factors suggested for study under (3) are type of fermentation vessel, preparation of inoculum, concentration of substrate, temperature, pressure, agitation, pH, and the kind and quantity of nutrient.

with regard to nitrogen and oxygen requirements, other necessary elements, and accessory growth factors.

18. Pilot-plant operation of fermentation processes found through laboratory studies to have promise of industrial application. Research of this nature will not only afford a means of evaluating the commercial feasibility of new processes but will make available sufficient quantities of end products to allow extensive examination of their physical and chemical properties and the preparation and study of derivatives.

19. Improvement in efficiency of present industrial fermentation processes has been suggested by many as a fruitful field of research. The application of new knowledge regarding the biochemistry of these processes should result in higher yields, shorter fermentation period, and more efficient recovery methods.

20. Design of equipment: The development of improved equipment for specific types of fermentations should receive consideration. The type of equipment used in fermentation depends largely upon the nature of the particular organisms, that is, whether they are aerobic or anaerobic. Aerobic organisms require vessels of large surface area and comparatively little depth or provision for aeration and agitation in deep vessels. When dealing with anaerobic organisms, it is advantageous to use deep vats. Within recent years new types of equipment which permit the carrying out of highly oxidative reactions of an aerobic nature have been successfully developed, but it is thought that further improvements may be effected for certain types of fermentations.

Saccharification.

21. Fundamental studies of the chemistry involved in the degradation of saccharification of carbohydrates into fermentable forms should be undertaken. A more economical conversion method would materially reduce the cost of manufacture of ethyl alcohol. Investigations of this nature should include studies on biological agents as well as on purely chemical agents.

Motor fuels.

An exceedingly large percentage of the representatives of industry, educational institutions, and agricultural experiment stations suggested that a study of the production of motor fuels from agricultural materials be undertaken. Their specific suggestions relating to this subject are summarized as follows:

22. Laboratory and pilot-plant studies including: (1) Studies of a chemical, biological, and engineering nature on the production from agricultural materials of compounds or mixtures suitable for direct use as motor fuels or indirect use in motor fuels as blending or denaturing agents; (2) studies on relative costs and values of various producible fuel materials and the yields obtainable from specific raw materials; (3) studies on the relative value of various processes or unit operations and the relative efficiency of different types of machinery and equipment used in production processes; (4) designing, erection, and supervision or operation of demonstration plants for motor fuels; (5) investigation on the possibility of using solid fuels for automobiles; and (6) the design of engines suitable for use with new types of fuel.

23. Economic studies on: (1) The use, performance, distribution, and marketing of agricultural fuel blends and the possible impact of production and use of new fuels on existing industry; (2) geographic distribution and availability of the raw materials; (3) locations for producing plants in relation to raw-material production and concentration; (4) developments in foreign production and use of alcohol fuels for power; and (5) possible future competition from fuels producible from nonagricultural materials other than petroleum.

24. Maintenance of a research and advisory organization to study all national and international developments on the subject of motor fuels and to give advice and assistance in the design, erection, and operation of demonstration plants by pioneering groups to aid in building a national industry.

Byproducts and wastes.

A summary of suggested research projects relating to the utilization of corn byproducts and wastes follows:

25. Protein studies, including: (1) Isolation and purification of zein from gluten; and (2) determination of the physical and chemical properties of the corn proteins as a foundation for their utilization in plastics.

26. Comprehensive study of steep water and hydrol from wet processing as possible sources for inositol and other organic chemicals.

27. Studies on corn to determine the chemical constitution and physical structure of the fractions isolated in the wet and dry milling of corn.

28. Investigation on fermentation residues as possible sources of vitamins, proteins, and other valuable chemicals.

29. Nutritional studies to determine the feeding value of mold mycelia, distillers' grains, and distillery slop.

30. Utilization of carbon dioxide from fermentation plants as a possible raw material in organic synthesis, and of solid carbon dioxide (dry ice) as a mechanical tool in industrial operations, as well as to a larger extent in refrigeration.

WHEAT

The United States produces about 15 percent of the world's wheat, as compared with nearly 50 percent of the world's corn and cotton. The total harvested acreage of wheat in this country during the 10-year period 1927-36 averaged 55.3 million acres. This was divided, roughly, into 37.3 million acres of winter wheat and 18.0 million acres of spring wheat. Wheat production in the last 10 years averaged 755 million bushels. The crop of 1937 totaled 876 million bushels; and that of 1938, 931 million bushels.

There are several fairly well defined wheat-growing areas in the United States which, for the purposes of this discussion, may be described as follows: (1) The eastern, soft winter wheat region; (2) the northern Great Plains area, producing chiefly hard red spring and durum wheat; (3) the southern Great Plains area, producing chiefly hard and semihard winter wheats; and (4) the intermountain and Pacific region, divided into a number of subareas by topography, producing numerous varieties of several wheat types, both white and red, including soft, semihard, hard, common or vulgare, and club or compactum, as well as hybrids of these and other genetic species.

Kansas is by far the leading State in winter wheat production, growing in the neighborhood of 150 million bushels annually. The other chief winter wheat States are Oklahoma, Nebraska, Ohio, Illinois, and Texas. The leading spring wheat (other than durum) State is North Dakota, which produces about 50 million bushels a year. The other important spring wheat States are Montana, Washington, South Dakota, Minnesota, and Idaho. Durum wheat is produced chiefly in North Dakota, South Dakota, and Minnesota. An average of about 40 million bushels of durum wheat is grown annually.

Wheat is the second most important cash crop of American farms, ranking next to cotton. In 1937 wheat brought farmers a gross income of 618 million dollars, compared with 884 million dollars from cotton. The gross income from wheat in 1936, a drought year, amounted to only 464 million dollars. The movement of wheat to market begins in June, when about 5 percent of the crop is moved. July is the month of heaviest movement, with 22 percent of the crop normally going to market in that month. The movement in August amounts to 20 percent of the crop; in September, 14 percent. The flow then dwindles down to its low point in the following April.

For the 10-year period 1928-37, it is estimated that the average total wheat disappearance in the United States, 683 million bushels, was as follows: 85 million bushels for seed; 118 million bushels for feed; 480 million bushels for food; in addition an average of 70 million bushels, including flour in terms of wheat, were exported. The quantity of wheat ground for food varies little from year to year, whereas that used for livestock feed largely accounts for variations in the total annual domestic disappearance. Changes in the number of acres seeded results in significant changes in seed requirements in some years.

What is customarily considered the "wheat problem" in the United States had its beginnings in the World War. Before that time a fairly stable condition in wheat growing and marketing was being approached. About 20 percent of the usual crop was sold abroad. In 1912, for instance, 730 million bushels of wheat were produced; 20 percent of it—144 million bushels—was exported. About half as much was exported in each of the two preceding years. In other words, no more wheat was grown than could be used and exported profitably.

The World War, however, changed the picture entirely. The United States, Canada, Australia, and the Argentine turned to wheat farming on a large scale. Following the war, Europe again resumed its wheat growing and our export trade suffered a severe slump. Thus the average net exports of wheat from the United States for the 10 years 1917-26 were 206 million bushels. The average exports during the 10 years 1927-36 decreased to 70 million bushels, much of it moving at very low prices. The result was a gradual accumulation of supplies, which, together with large supplies in other countries, reduced the price on the world market to distress levels.

About 1928 the surplus situation became critical. That year a bumper world wheat crop, about 4 million bushels, not including China and the Union of Soviet Socialist Republics, was produced. Following that season, an annual surplus continued to ride the world markets, forcing prices down to levels generally below cost of production. Not only did good crop seasons favor the large wheat countries, but importing nations took more and more steps to bolster prices within

their own borders and stimulate home production. Moreover, European trade regulations such as special tariffs, embargoes, quotas, and exchange restrictions, coupled with the cessation of loans by the United States to foreigners, placed sharp limitations upon our export market. In spite of this situation the area seeded to wheat in the United States for harvest in 1937, and again in 1938, amounted to about 80 million acres, the largest wheat seedings ever made.

World supply and demand make the real wheat market, and at present world wheat production is still gaged to a level above normal requirements. Present world acreage of approximately 285 million acres is about 15 million acres larger than necessary to meet the usual requirements of consumption. Therefore such reduction as may occur in this country in the coming year is likely still to leave us with a rather unfavorable surplus and price situation.

Because production of wheat has been much greater than utilization, large carry-overs have resulted and the price has accordingly declined. Carry-over in the United States of the crop of 1937, amounting to 154 million bushels, added to the 1938 crop of 931 million bushels, made the total supply of wheat in the fall of 1938 exceed a billion bushels. It is estimated that the carry-over in July 1939 will amount to about 300 million bushels, almost equal to the average carry-over for the 1930-34 period—325 million bushels—when stocks reached record size. The carry-over and the weighted average prices, as received by wheat producers in all parts of the United States in recent years, are given in the following table:

TABLE 2. *Carry-over and price of wheat, 1923-38*

Year beginning July	Carry-over	Farm price per bushel	Year beginning July	Carry-over	Farm price per bushel
1923-27 (average)-----	118, 000, 000	\$1. 20	1935-----	148, 000, 000	.83
1928-32 (average)-----	264, 000, 000	.69	1936-----	¹ 142, 000, 000	1. 03
1933-----	378, 000, 000	.74	1937-----	83, 000, 000	.96
1934-----	274, 000, 000	.85	1938-----	² 154, 000, 000	-----

¹ Prior to 1937 the carry-over contained some new wheat, in some years probably amounting to about 20 million bushels.

² Preliminary.

It is interesting to note the relation between carry-over and price—an increase in carry-over generally results in a decrease in price (see the accompanying chart). This is largely because the carry-over in the United States and that in the world usually move together.

Most of the sound, high-grade wheat grown and processed in recent years have been converted into human food—bread, biscuits, cakes, alimentary pastes, and cereal breakfast foods. The amount of wheat fed to livestock on the farm where grown varies widely from year to year. In commercial animal and poultry feeds containing wheat, this ingredient, in normal years, is chiefly wheat unsuitable for milling. Byproducts of the milling industry are used largely as feeds or as ingredients in mixed feeds. There is a growing use of wheat by-products in poisoned baits for insects.

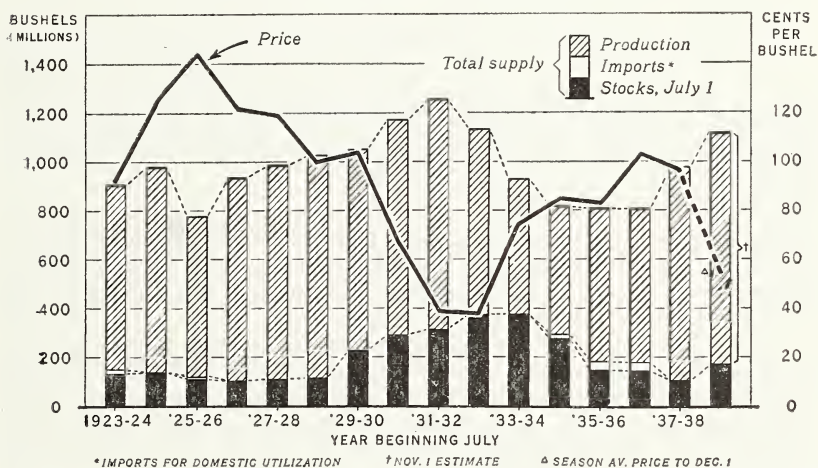
While special types of milling are employed in manufacturing certain food and feed specialties, the bulk of the wheat now milled is processed by roller milling. The flour milling industry is highly standardized and mechanized, and has been so for a longer period than have most of the other food processing industries of this country.

PRESENT RESEARCH

Since wheat has been used chiefly in human foods and in animal feeding, fundamental and applied research has naturally been directed particularly to its adaptability to such uses. These researches deal with the biochemistry and technology of wheat, through the genetics of breeding and reproduction, culture or agronomic phases, harvesting, merchandising, grading, storing, and numerous processing operations, as well as the nutritional aspects. Since many fundamental chemical and physical properties of wheat and wheat products are being covered in these researches, they are of direct interest in any survey dealing with the utilization of wheat or wheat products.

The following major divisions of this research have been chosen as a matter of convenience: Wheat production and storage; processing of wheat; wheat flour and specialties; and byproducts. Under these headings have been grouped those research projects now in progress which have a bearing on possible industrial utilization of wheat and its byproducts.

WHEAT: U. S. SUPPLY AND WEIGHTED AVERAGE PRICE RECEIVED BY FARMERS



U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

Wheat production and storage.

1. Genetic and breeding studies to develop resistance to black stem rust, bunt or stinking smut, and other diseases and insects; to hasten date of maturity; to improve cold resistance or winter hardiness in fall-sown or winter wheats; and to produce strong, high-gluten bread wheats and soft starchy wheats for pastry and cake baking; with parallel studies of the effects of genetic characteristics, plant diseases, insect infestations, and frost damage on the composition and technological properties and characteristics of wheats.

2. Investigations of environmental influences upon the composition of wheat, including: Available moisture from rainfall or irrigation; effect of soil nutrients, their concentration, and the time and manner of their application to the soil; and temperature and related climatic variables.

3. Cultural and harvesting studies in their relation to control of insect pests, and to composition and quality of wheat, including: Combine harvesting under varied climatic conditions; relation of stage of maturity at time of harvest and of various methods of handling summer fallow to composition and technological properties; effect of previous crops, particularly of legumes, upon the composition and properties of succeeding wheat crops; and effect of damaged, shrunken, and broken kernels, and of foreign material, upon the composition and properties of bulk wheat.

4. Wheat-storage investigations, such as: Influence of relative soundness or freedom from damage, foreign materials, moisture content, temperature, ventilation, size of kernel, control of insect pests, and other factors upon the respiration and keeping qualities of the stored grain; and relation of stored-grain pests, including fungi, bacteria, insects, and mites to bulk temperature, to the destruction of grain substance, and to the modified composition and properties of infected wheat.

Processing of wheat.

5. Investigations on wheat conditioning or preparation for milling, including control of the moisture content, and thermal and chemical treatments.

6. Milling studies on: Composition and technological properties of the intermediate and final products of milling, and the combination of the latter into finished flour streams; chemical treatments, including flour bleaching with various agents such as halogens, organic peroxides, etc.; and manufacture of durum semolinas and graham or whole-wheat flour.

Wheat flour and specialties.

Research on manipulation and materials involved in the utilization of wheat flour is directed almost entirely to a more exact control of baking operations and to improving the quality of bakery products. It falls into the following groups:

7. Dough studies: The physical properties and chemical reactions of doughs as they are affected by type and quality of flour, composition, and other factors; the relationship of dough properties to the protein and starch contents of wheat; and the effects of the proteolytic, amylolytic, and fermentation enzymes on the production of doughs and finished bakery products.

8. Baking investigations: The biochemistry and chemical technology of bread baking, and the development of new and improved practices in the production of hard breads, crackers, cookies, cakes, pastries, and fancy cakes.

9. Specialty food products: Highly specialized studies dealing with various problems involved in the production of breakfast foods, malted wheat flour, and alimentary pastes such as macaroni, spaghetti, and noodles.

10. Miscellaneous studies: Effects of "bread improvers"; development of chemical leaveners; retarding the staling of bread; and development of methods for the control of mold and "rope."

Byproducts.

11. Utilization of byproducts: Isolation, purification, and characterization studies of wheat protein; investigation of wheat germ and wheat-germ oil as dietary supplements and pharmaceuticals; attempts

to improve edible bran as a dietary supplement; evaluation by conventional analyses and biological assays of milling byproducts used in animal feeding, including bran, shorts, or middlings of different grades, red dog, and low-grade flour; testing of milling byproducts as attractants and carriers in poisoned baits for insects; and industrial utilization of wheat straw. (See section on Agricultural Wastes, p. 50.)

SUGGESTED RESEARCH

No direct reference is made in this section to utilization of wheat in food products, but it should be recognized that when additional fundamental facts become known through new studies directed toward industrial utilization of wheat, they may find useful application in the food fields as well.

For convenience, suggested research on wheat has been divided into two sections, fundamental research and technological research. In the first are included studies of composition, constitution, and properties of wheat and wheat constituents without specific reference to industrial applications, but rather with the idea of elucidating facts requisite to a sound program. In the second section is listed a series of suggested projects which have a well-defined industrial application and may be based either on fundamental knowledge or on observations made by a more or less trial-and-error procedure.

Fundamental research.

1. Genetic studies on the mechanism and possibilities of inheritance of kernel shape, texture, and other physical properties; disease and insect resistance, earliness, and cold resistance or resistance of winter wheat to freezing; important industrial properties, such as content of proteins, minerals, starch, sugars, fats, pentosans, and pigments.

2. Investigation on the influence of environment on the chemical and technological properties of wheat, including the relation of the soil minerals to those of wheat and the effect which these minerals exert upon the physical properties of wheat, and upon its products, constituents, and technological uses.

3. Crop surveys: Surveys of the characteristics of each crop should be made to serve as a basis for predicting the relative availability of various types and qualities of surplus wheat for industrial processing.

4. Wheat-storage studies, including: Respiration of wheat in storage; changes in the properties and composition of wheat kernels during storage; and consideration of the fungi, insects, and other organisms associated with bulk wheat, and the use of chemical and heat treatments for their control, in relation to its keeping qualities.

5. Investigations on wheat proteins, to include: Controlled hydration and hydrolysis of wheat proteins; quantitative recovery, fractionation, and purification of wheat proteins; and fractionation and purification of the products of partial and complete hydrolysis of wheat proteins. (For further details see Protein Studies in the section Dairy Products, p. 298.)

6. Starch studies, to include: Fractionation and recovery of starch components; chemical constitution of these components; and chemical, biochemical, and physical manipulation of the amyloses, as in hydrolysis, oxidation, and reduction reactions. (For further details of a program which should be accompanied by similar work on wheat

starch, see the section, Wet Milling of Corn, Fundamental Research on Starch, Starch Derivatives and Sugars, under Suggested Research on Corn.)

7. Chemical investigations on minor constituents such as wheat-germ oil, vitamin E, vitamin B, and natural fat antioxidants.

8. Fermentation studies: Investigations on fermentation of wheat and of wheat constituents or derivatives; action of special yeasts, bacteria, and molds or other fungi on wheat proteins and carbohydrates (starch in particular), and on other materials prepared from wheat as substrates, with a view toward producing new chemicals for use as reagents, or for syntheses and special applications; recovery of useful enzymes and enzyme concentrates from such cultures; and special fermentations which may be induced by these organisms or by the enzymes thus recovered. (For further details, see suggested research under Fermentation, in section on Corn, p. 34.)

Technological research.

9. Wheat-milling studies, with particular reference to: Recovery of special types of flour or meal to be used in various industrial applications; increased recovery of wheat germ, only about one-tenth of which is now recovered in even a reasonably pure (60 to 70 percent) form in ordinary milling operations; and recovery of purified bran and its utilization in the production of enzyme, vitamin, and mineral extracts or concentrates for use in supplementing the nutrients of white or patent flour bread.

10. Technological manipulation of wheat flour of various grades or degrees of refinement, produced from wheats of varying composition (particularly in terms of gluten content), to determine the usefulness of such flours and flour derivatives as the basic materials of adhesive pastes, binders for briquets and foundry cores, sizings for leathers, and related or new applications.

11. Technological studies on wheat starch to ascertain whether it or its derivatives possess any unique properties which would facilitate their use in special cases to be developed, and whether it or its derivatives might be substituted in whole or in part for starches now imported into the United States for use as adhesives, in sizings, or for other purposes.

12. Industrial fermentation studies based upon application of existing knowledge and the results of such fundamental researches as are outlined under item 8, of this section, and with due attention to the utilization of low-grade as well as sound wheat as a raw material; and milling, decorticating or peeling, and degerminating [methods, to receive attention in an effort to effect the economical separation and utilization of all parts of the wheat kernel.

13. Technological investigations on wheat proteins, notably the gluten proteins from the endosperm, including the development of industrial processes for quantity recovery and purification of the proteins collectively and individually, and their utilization in the production of plastics, fibers ("artificial wool"), and paper size and for other applications which may be developed. Particular attention should be given to the recovery and use of the gluten proteins in the durum wheat flour which is a byproduct in the manufacture of durum semolinas.

BARLEY

Approximately 10 million acres have been planted to barley in the United States in recent years. The average annual yield over the 10-year period 1928-37 was around 230 million bushels, which represents about 10 percent of the world production. Barley is grown in appreciable quantities (over a million bushels) in 25 States with production centered in Minnesota, North Dakota, California, South Dakota, and Wisconsin. This cereal ranks about with oats in cash farm income, with a gross return of 45 to 60 million dollars per year. During the World War the price of barley rose to a high level, more than a dollar a bushel, but shortly thereafter dropped to half that figure. In recent years it has ranged from around 40 to 75 cents a bushel. On March 1 of recent years commercial stocks have totaled only from 10 to 15 million bushels, and while stocks carried over from year to year do not measure a surplus situation it is probably correct to say that there is no acute surplus problem in the case of barley. Any expansion in barley acreage in the last 12 years has been largely in areas where the grain is used primarily for feed.

CROP DISPOSAL

Barley is used chiefly as a feed grain, being substituted for corn to some extent. It is frequently ground with oats or other grains as mixtures. As a feed it is used largely for horses and poultry and in the finishing of bacon hogs. That portion of the crop which reaches terminal markets finds four principal outlets in (1) malting, (2) feed, (3) food, and (4) export. Export trade is small and has ranged from 4 million to 60 million bushels annually over the period 1927-36. Imports, on the other hand, ranged from 1 million to 28 million bushels annually over the same period.

INDUSTRIAL UTILIZATION

While barley constitutes no more than 6 percent of the total quantity of cereals produced in the United States, from the industrial point of view it is surpassed in importance among the grains only by wheat and corn. Approximately one-fourth of the crop is malted, and this outlet accounts for the greater part of the barley that finds its way to the cash markets. In the calendar year 1937 about 61 million bushels of barley were malted. By far the largest consumption of malted barley is in the brewing and distilling industries, although important quantities find outlets in malt sirups, malted-milk beverages, malt flour, and other food products. Only relatively small quantities of barley are used in the manufacture of barley flour or as a breakfast food. Pearl barley is employed in food products such as soups and dressings.

PRESENT RESEARCH

Investigations currently under way are directed largely toward the utilization of barley for malting purposes and toward the production of malt products. The important lines of attack, described as follows, have been divided into two groups, agricultural and technological.

Agricultural.

1. Genetic studies on the morphological and physiological characters of the barley plant.
2. Breeding for resistance to the diseases that cause large losses in some years.
3. Breeding for improved yield, stiffness of straw, smooth beard, drought resistance, and malting quality.
4. Studies to discover which varieties are best to use in breeding programs and which method of breeding is most effective.
5. Entomological studies of the insects attacking barley and their control.
6. Agronomic studies on the influence of varietal and environmental factors such as soils, the application of fertilizer at different stages of growth, methods of culture, time of harvest, conditions of storage, and other variables upon the yield, chemical composition, and malting properties of barley.
7. Agronomic studies on winter barley to determine which varieties are most winter hardy and which are best suited for pasture, cover crop, and grain yield.
8. Studies on the correlation of the physical and chemical characteristics of barley produced under different environmental conditions with their malting properties, for the purpose of formulating standards and grades of malting barley.
9. Investigations to determine the effect of environmental factors during malting (1) upon the transformations of proteins, carbohydrates, etc.; (2) upon the development of the various enzymes and their potency; and (3) upon the relation between the nitrogen fractions of barley and malt and the diastatic value of the malt.
10. Biochemical studies, including the diastatic value, on malt derived from various strains of barley.

Technological.

11. Studies on the relation of the size of the barley kernel to quality of the malt produced therefrom.
12. Histological studies on the barley kernel during malting.
13. Standardization of present laboratory methods.
14. Development of simpler, better, and more dependable laboratory methods for evaluating malts.
15. Studies on the effect of moisture, time, and temperature during malting on the quality of malts produced.
16. Studies correlating the quality of malts produced in experimental plants with those obtained from commercial plants.
17. Development of midget malting methods suitable to test hybrid barleys.
18. Improvement of the quality of malt products destined for food or technological processes (1) by determining the cause and prevention of thickening and crystallization of diastatically active malt sirup; (2) by eliminating microflora from such products; (3) by developing methods to enhance the keeping quality of bulk sirup and extracts; (4) by prevention of hygroscopicity of dried malt sirups; and (5) by developing new methods of packaging hygroscopic malt products.
19. Investigation of malt sirups as flavors for cereal food products.
20. Enzymic investigations on the potency and value of malt solutions useful for various technological processes and on the role played

by the enzymes in the malting process. New uses for these materials are being developed.

21. Preservation of partially concentrated malt solutions with particular reference to compounds suitable for removing starch from sized goods, and development of special extracts suitable as desizing agents and for other industrial purposes.

22. New industrial uses of brewers' and distillers' grains, spent hops, and excess yeast.

SUGGESTED RESEARCH

While considerable research is being carried on with barley, fundamental work on a more elaborate scale is essential. It is quite natural that suggested research work should center for the most part around malt and malt products. The suggested research listed below is classified in three divisions—agricultural, fundamental, and technological.

Agricultural.

1. Varietal and environmental factors to determine the effect of climate, soil composition, fertilizers, diseases, insect infestation, etc., upon the quality of barley for malting purposes; the nature of the proteins; the vitamin and mineral content; the changes in the composition of barley during growth and as the result of different methods of harvesting; the quality of beer; and the food and industrial value of malt extract and sirup.

2. To study the heritability of the various malting quality factors so as to make intelligent use of them in a breeding program.

3. Storage investigations on the effect of age and the conditions of storage (including insect infestation and the use of insecticides) upon the germinating and malting quality of barley.

Fundamental.

4. Investigations on the process of malting, including the isolation of the various enzymes, and a study of their properties and their role in brewing and other industries.

5. Histological and microchemical studies on the germinating barley seed with reference to structural and physiological changes. Similar studies should be made on the enzyme-secreting areas.

6. Barley and malt protein and starch studies, including the biological value of the proteins.

Technological.

7. Development of a method for a rapid test that will evaluate for commercial inspection purposes the malting properties of barley.

8. Study of the effect of temperature, moisture, and age on barley malt in storage.

9. Studies on the malting process, e. g., the effect of (1) temperature of the water on time of steep; (2) acids, bases, and salts in steep water; (3) the use of catalysts in the germination process; (4) temperature of kilning; (5) production of sterile malt sirup and malt sugars; (6) development of high enzyme malt; and (7) production of malt flavor and dry malt extracts with minimum hygroscopic properties.

10. Correlation of the character and composition of malts produced from different kinds of barley with the nature of the beer brewed under definite conditions so that any brewer can be supplied

a malt that will be best suited to his process of brewing. This should require a model experimental malting plant and brewery of at least 25-50 bushel or barrel capacity.

11. Brewing studies (1) to determine the effect of air and impurities on the quality and haziness of the beer and how to eliminate them; (2) to develop methods of sterilization; (3) to stabilize foam; and (4) to improve the quality of beer.

12. Studies to determine the effect of variations in temperature and time during mashing, boiling, etc., on the quality of beer obtained.

13. Studies correlating yeast propagation with malts of different quality.

14. Studies to extend uses of high diastatic malt extract in the wall-paper, laundry, and textile industries.

15. Study of malt as a possible coffee substitute.

16. Studies on the use of malt sirup or extract as a source of food by people on relief. This would not only supply the needy people with an excellent food but would make it possible for many breweries which operate only 3 to 4 days per week to work more hours.

17. Studies directed toward the utilization of malt culms, brewers' and distillers' grains, especially in the manufacture of plastics, adhesives, etc., and by bacterial and mold fermentation for the production of technological products. About 375,000 tons of brewers' grains are produced in American breweries, a large part of which is wasted.

18. Study of brewers' excess yeast as a source of vitamins, ergosterol, and other products of irradiation by ultraviolet light or otherwise; in the food industries for the production of a concentrated yeast extract with high vitamin and mineral content for pharmaceutical and medicinal purposes.

19. Utilization studies of barley unsuited for malting (1) in the production of enzymatic preparations; (2) in the preparation of other products by means of autolysis, digestion, and fermentation.

20. Utilization studies of barley straw (6,000,000 tons available) as a source of raw material for paper, wallboard, insulating material, fuel, oil, gas, etc. (See Agricultural Wastes.)

OATS

The United States produces 25 percent of the world's oats, the farm value to the American farmer being over 350 million dollars. The cash income from oats sold off the farm is 50 to 60 million dollars, or about 1.5 percent of the farm cash income from all crop sources.

In actual tonnage, the oat crop is the third largest cereal crop of this country, the average yield being 18 million tons as against 24 million tons of wheat and 66 million tons of corn. Oats make up about 16 percent by weight of the cereals produced in the United States. In recent years the area sown to oats has averaged about 37 million acres and the crop ordinarily yields about 1 billion bushels. This tremendous output of oat grain is accompanied by over 23 million tons of straw and about 3½ million tons of hulls. Iowa is the principal producing State with an average of about 200 million bushels. Other States in order of importance are Minnesota, Illinois, Wisconsin, Nebraska, Ohio, and Indiana.

Oats are the principal small grain fed to livestock. Replacement of work horses by tractors and of horse-drawn vehicles by automobiles has seriously affected the prices of oats and has tended to decrease production. Of secondary importance in the disposal of oats is the quantity exported and the fraction diverted to human consumption. Net annual exports of oats during the past 15 years have averaged less than 10 million bushels. In the last 4 or 5 years exports have been practically nil. The quantity processed for breakfast food (oatmeal and rolled oats) is about 26 million bushels annually or about 2.5 percent of the total production. Oat food products produced each year comprise between 450 and 550 million pounds, or 43 percent of the total output of breakfast foods. The value of these oat breakfast foods is about 25 million dollars, or one-fourth that of all products in this class.

In the manufacture of oatmeal and rolled oats, there are produced some 135,000 tons of hulls. Today, oat hulls constitute the only raw material being used commercially for the production of furfural. As the yield of furfural is about 10 percent of the weight of the raw material, the potential output is 27 million pounds. Current production of furfural does not yet approach this figure. (For further discussion see Furfural in the section on Agricultural Wastes.)

PRESENT RESEARCH

The principal research on oats now under way deals with the oat crop itself. There is relatively little study being made of the pressing problem of crop outlets, especially from the industrial point of view. Studies now in progress may be summarized as follows:

Agricultural.

1. Investigations in oat improvement by breeding for yield, quality, disease resistance, etc.
2. Agronomic studies to determine the effect of climate, soil, fertilizers, methods of culture, date of seeding, time and method of harvesting, etc., on the physical and chemical quality of the grain.
3. Investigations of the characteristics, structure, classification, and distribution of oat types and varieties.

Processing.

4. Improvement of the technological milling of oats.
5. Separation, chemical study, and utilization of the germ, shorts, and middlings, and also the hulls.

Utilization.

6. Production of various useful chemical and industrial products using as a basis the furfural obtained from oat hulls.
7. Use of oat products as antioxidants for the prevention or delay of rancidity in oil-bearing foods.

SUGGESTED RESEARCH

Such research on oats and oat products as was suggested during the course of this survey is summarized as follows. In some cases this involves merely an extension of work already in progress.

Agricultural.

1. Studies such as breeding of oats to improve the possible industrial, food, and feed value, especially the mineral and vitamin content of oat grain.

2. Determination of the influence of variety, climate, soil, soil minerals, fertilizers, methods of culture, harvesting, etc., on the quality and mineral content of oats and the consequent effect on industrial utilization.

Fundamental.

3. Investigations of the physical and chemical properties of the carbohydrates, protein, oil, and fiber of oat grain, straw, and hull.

4. Application of these studies to possible industrial uses.

Utilization.

5. Use of oat hulls and oat groats as antioxidants and retarders of spoilage of fat-bearing materials.

6. Determination of the relative merits of malt made from oats for industrial purposes.

Wastes.

7. Studies on oat straw and hulls for the production of fuel oil, gas, cellulose, building board, insulating and absorbent materials, drugs, paints, varnishes, etc. (See *Agricultural Wastes.*)

MINOR GRAINS

Of the so-called minor grains—sorghum, rice, rye, buckwheat, and millet—the first named is the most important from the standpoint of acreage, yield, and farm value. Rice is second in importance in yield and farm value. Buckwheat and millet are the least important.

The grain sorghums, including kaffir, milo, feterita, durra, etc., which are among our most drought-resistant crops, have an important place in the agricultural economy of the semiarid regions of the United States. They bring a gross farm income of 5 to 6 million dollars a year. The total land devoted to grain sorghums ranges from 7 to 9 million acres, and the yield averages 11 to 15 bushels an acre. Ordinarily, somewhat more than half the acreage is harvested for grain, the remainder being used as forage. The average annual output of grain sorghums from 1927 to 1936 amounted to about 90 million bushels. In 1938 the crop increased sharply; it is estimated at 107 million bushels. Texas is by far the largest producing State, annually harvesting more than 50 million bushels. Oklahoma, Kansas, New Mexico, California, and Colorado rank next in importance.

Grain sorghums are used almost exclusively for animal feed, and are fed chiefly on the farm. The proximate composition of the grain is similar to that of corn (maize), except that the oil content is somewhat lower. This would indicate that sorghum grain might be used for the production of starch, edible oil, and certain byproduct feeds, just as corn is now used. The germ of the sorghum grain constitutes 10 percent of the kernel by weight, and contains more than 30 percent of oil, being in that respect very similar to the germ of corn.

Rice is a sectional crop, 80 percent of its production being confined to Louisiana, Texas, and Arkansas. Most of the remainder is grown in California. The total rice crop occupies about a million acres, and

37 to 53 million bushels are grown annually. Rice is used essentially as a food grain. From 1 to 2.5 million bushels are used annually in the manufacture of fermented malt beverages. In addition to a comparatively small international trade, more than 10 million bushels (20 to 25 percent of the total United States production) are shipped yearly to Alaska, Hawaii, and Puerto Rico. The surplus of rice is particularly large this year (1938-39). Probably less American rice will be used during the coming season than was used last year, with the result that large stocks will be carried over into the 1939-40 season.

Rye is grown mainly in the North Central States and in Pennsylvania. From 2 to 4 million acres are grown annually, yielding 17 to 58 million bushels of grain, with a farm value of 12 to 34 million dollars. The price of rye varies considerably. In 1936, a year of short crops, the price averaged 81 cents a bushel, and in 1938 it declined to less than 35 cents a bushel. Rye is utilized both as a food and as feed. Furthermore an appreciable quantity is used industrially in the manufacture of distilled alcoholic beverages and ethyl alcohol.

Buckwheat and millet are relatively unimportant crops. Buckwheat is largely a food grain. From 6 to 9 million bushels are produced annually, mainly in New York and Pennsylvania. The farm value is from 4 to 5 million dollars. Millet is a drought-resistant crop grown essentially for forage and pasture. About one-half million bushels of millet seed, used as poultry and bird feed, are produced annually.

PRESENT RESEARCH

With the exception of limited agronomic studies little work of importance is being done on rye and buckwheat. The research now in progress on the other minor grains may be summarized as follows:

1. Agronomic studies on sorghum. These studies cover (1) the characteristics, structure, and classification of different varieties; (2) the influence of variety, soil, fertilizers, environmental factors, method of cultivation, time of harvest, etc., on the market quality and composition of the grain; and (3) the influence of varietal, cultural, and environmental factors on the physical and chemical properties and utility of the proteins, oil, and carbohydrates of the grain.

2. Agronomic studies on rice, including the influence of variety, soil, fertilizers, methods of culture, time and method of harvesting, method of storage, etc., on the yield and milling quality of the grain.

3. Nutritional studies with sorghum grains and stalks.

4. Physical and chemical investigations of the sorghum proteins, oils, and carbohydrates, and their adaptability for technological uses.

SUGGESTED RESEARCH

Problems suggested for research may be classified as follows:

Agricultural research.

1. Studies to determine the influence of the genetic, varietal, and environmental factors on the chemical and physical properties of the components of the minor grains.

Fundamental research.

2. Studies on the mineral and vitamin content of the grains.

Storage.

3. Studies to determine the changes taking place during storage and the effects of such changes on the quality of the various constituents of the grains.

Utilization.

4. Studies on the utility of the carbohydrates, proteins, and oils of the grains for the manufacture of starch, alcohol, adhesives, plastics, paints, etc. Rice starch, because of its peculiar characteristics, is of particular technological interest.

5. Investigations on the malting properties and the diastatic and proteolytic enzymes of the grains to determine their adaptability for use in fermentation processes and for other technological purposes.

6. Studies on rye bran and germ and on rice bran and polish as possible sources of vitamin and mineral concentrates and of oil for pharmaceutical and medicinal purposes. (About 150 million pounds of rice bran and 30 million pounds of rice polish are available.)

7. Investigations to determine the possibility of using the by-products, including buckwheat hulls, buckwheat straw, sorghum stalks, rye straw, rice straw, and rice hulls, for the manufacture of industrial products such as solid, liquid, and gaseous fuels, cellulose paper, wallboard, and charcoal. (See also *Agricultural Wastes*.)

AGRICULTURAL WASTES ¹

Agricultural wastes here referred to include straws, stalks, stems, hulls, cobs, shells, pods, bagasse, etc. Hulls, cobs, peanut shells, and bagasse are included because of their chemical and physical similarity, but hard nutshells are grouped with fruit pits under cannery or processing wastes, discussed elsewhere. Weeds or other uncultivated vegetation on unused or abused land are considered in this discussion because the problems of utilization are similar, but no estimates of the amounts of these growths are included in the following discussion. Wood and wood products are discussed in the section on *Forest Products*.

Agricultural wastes are used for feed, fuel, bedding, litter, and other farm purposes, and small amounts are used as fuel in homes and industries, but practically all require special effort on the farmer's part to dispose of them. Sometimes they are burned, the mineral constituents alone returning to the soil, but more often they are left to rot or are plowed under, returning to the soil organic and inorganic material in the form of humus.

Owing to their variety and the many crops of which they are a part, agricultural wastes of the class under discussion are found in practically every producing region, but they are concentrated in the cotton area and in the corn, wheat, and other grain-producing areas. It is estimated that between 165,000,000 and 200,000,000 tons of bone-dry agricultural byproducts are produced annually (table 3). Probably half of this amount is available for industrial utilization because of its location in heavy producing areas or because of other economic considerations attendant upon its harvesting or collection. Its farm value ranges from that of low-grade fuel to that of a filler or roughage

¹ The term "agricultural residues," although not so commonly used as "agricultural wastes," would be more exact. Cereal straws, for instance, play a definite part in the farm economy, even though the proportion actually used is minor.

component of feeds. A very conservative estimate of this farm value would be several hundred million dollars annually. Research work on agricultural wastes has been responsible for development of the straw-board industry, the production of structural insulation from bagasse, cornstalks, and straw, the production of furfural from oat hulls, and other industrial applications. But only a small proportion of the total amount available is used at present, mainly because of the difficulties of collection.

The magnitude of the quantities classified as agricultural wastes can best be indicated by comparison with other products. For instance, the total annual growth of timber is reported as 11,287,000,000 cubic feet, equivalent to approximately 180,000,000 tons of dry material. In 1936, 488,830,000 tons of coal were produced. In the same year the production of petroleum totaled 1,098,516,000 barrels, equivalent to 184,551,000 tons. The average annual human consumption of food in the United States is approximately 100,000,000 tons, which when reduced to dry weight is not more than 50,000,000 tons.

Few statistics are available on the crop byproducts discussed here as agricultural wastes. The only reasonably satisfactory way of estimating the production of these materials is to calculate the weights of the byproduct from the known production of the basic crop by the use of factors. Table 3, which has been prepared by the use of such factors, presents a fairly reliable picture of the average annual production of agricultural wastes for the 5 years 1931 to 1935. The figures in table 3 are fairly representative of current conditions, although the production figures for some crops have changed.

TABLE 3.—Average annual production of certain agricultural byproducts for 1931–35, inclusive

Byproduct	Grain per bushel	Dry by-product per pound of grain	Dry byproduct per bushel of grain	Average production of dry byproduct	Estimated quantity of dry byproduct available for industrial use
	Pounds	Pounds	Tons	1,000 tons	1,000 tons
Wheat straw.....	60	1.9	0.057	38,794	29,000
Rye straw.....	56	2.5	.070	2,378	1,800
Oat straw.....	32	1.3	.0208	20,156	0
Barley straw.....	48	1.2	.0283	5,965	4,474
Flax straw.....	56	4.0	.112	1,128	1,128
Rice straw.....	45	1.2	.027	1,089	820
Total straws.....				69,510	37,222
Corn cobs.....	56	0.22	0.00616	12,408	1,400
Oat hulls.....	32	.30	.0048	4,651	150
Rice hulls.....	45	.20	.0045	182	182
Cottonseed hulls.....				11,165	583
				183	92
Total cobs and hulls.....				18,589	2,407
Corn stover.....	56	1.2	0.0336	63,681	28,500
Cotton stems and pods.....				17,544	12,281
Bagasse fiber, continental United States.....				423	423
Bagasse fiber, insular United States.....				3,276	3,276
Total other byproducts.....				84,924	44,480
Grand total.....				173,023	84,109

¹ Reported production, but not limited to crop years specified.

² One-third of in-the-hull production.

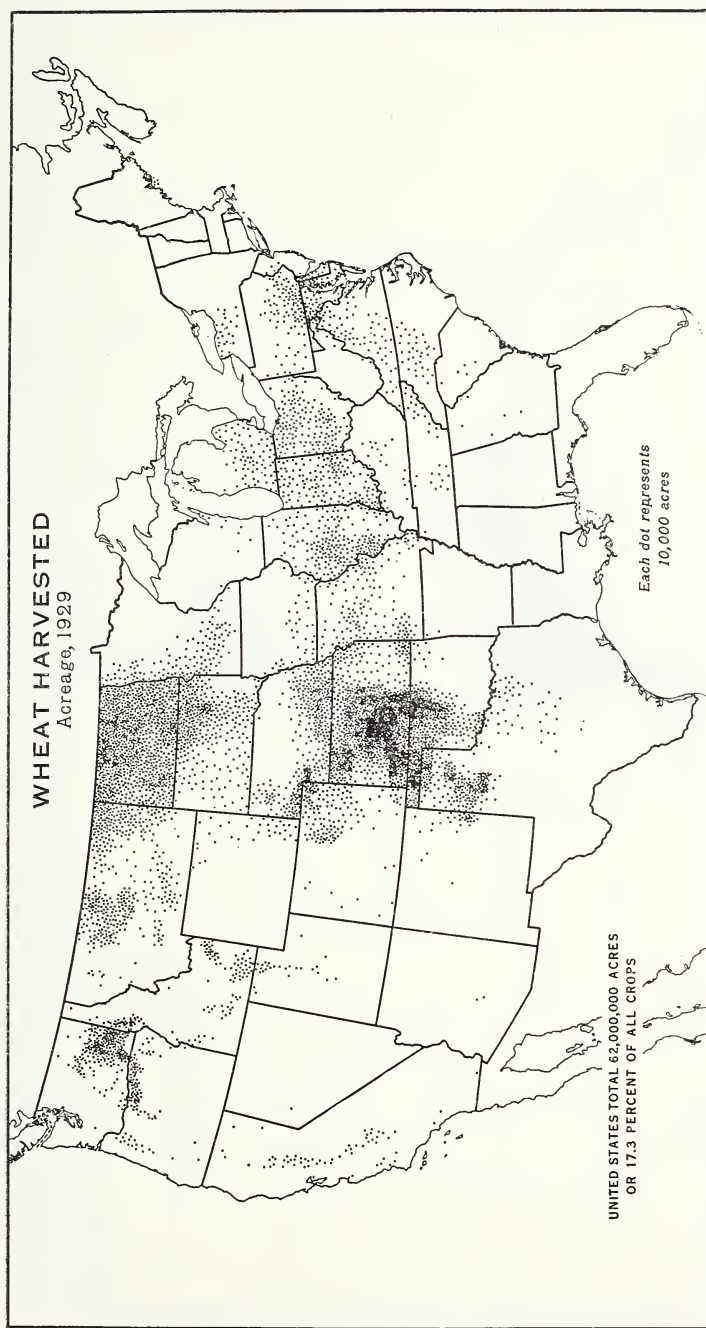
³ Calculated; 2:1 used as ratio of stems and pods to combined seed and lint.

⁴ Cane production x0.125 for Louisiana and Florida.

⁵ Cane production (x0.126 for Hawaii) (x0.12 for Puerto Rico and Philippine Islands).

In addition to the byproducts included in table 3, there are many similar wastes or wild growths which should receive attention. This group includes cacti, wild grasses, water hyacinths, palmetto, vines, tree prunings and trimmings, and many items which, in general, appear to be less interesting as raw materials because they occur in unusual locations or present difficulties of collection. The available quantities of these materials are very difficult to estimate.

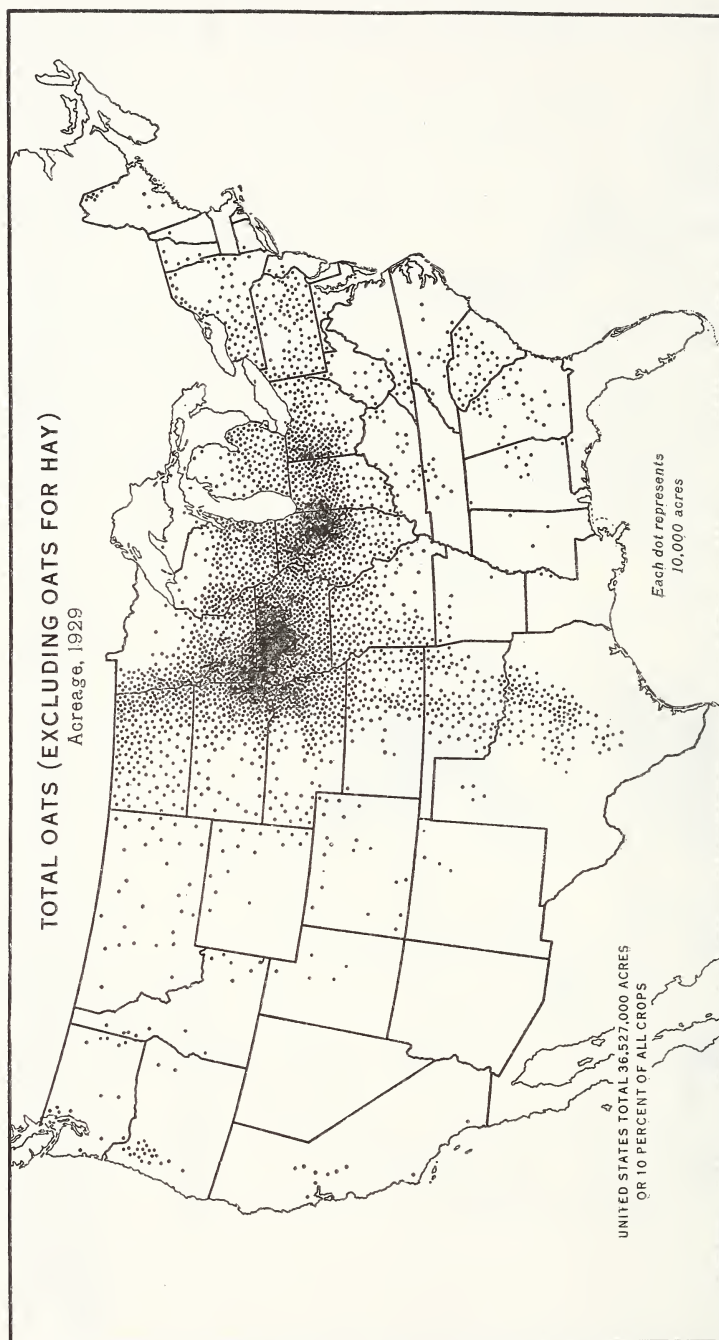
The geographic location of the areas producing agricultural wastes can best be indicated by maps showing the acreage devoted to the basic commodities. The following nine maps serve a double purpose. Producing areas are denoted by dots on the maps, each dot representing a unit of acreage. The density of production of any commodity is therefore represented by the density of the dots. The concentration of the dots indicates those areas in which industrial utilization would be favored because of heavy production and low transportation costs. In the other localities use on the farm or in nearby rural areas should be more practicable. These maps are the latest available, but it must be pointed out that some changes in production have taken place since 1929, the year represented by each of them. In general, however, the relative production density remains the same.



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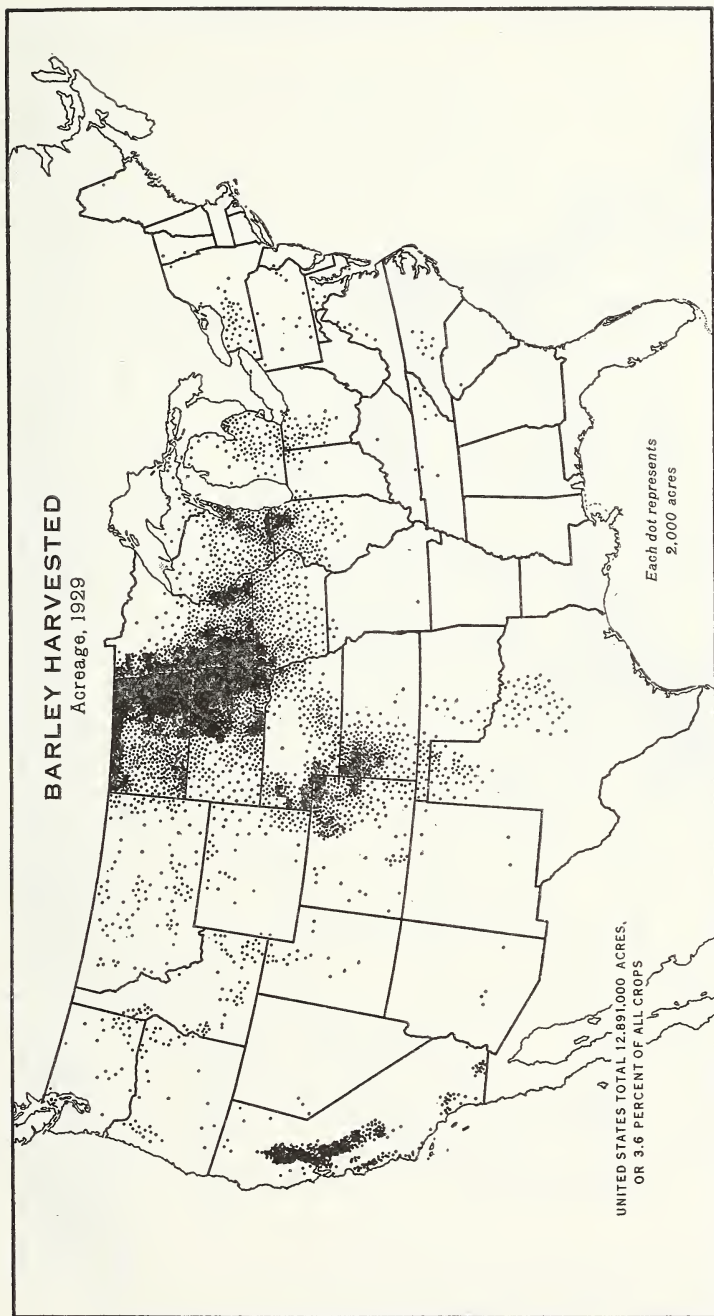
The United States produces about one-fifth of the world's wheat, as compared with nearly three-fifths of the world's corn and cotton. Seventy percent of the wheat acreage was in the Great Plains States in 1929, and wheat is an important cash crop entering into the rotation of the eastern Corn Belt, and of the limestone valleys and Piedmont from Pennsylvania to North Carolina. The wheat region of the Great Plains is divided by the Nebraska Sand Hills into the Hard Winter Wheat Belt to the south and the Hard Spring Wheat Belt to the north. The Columbia Plateau produces both winter and spring wheat.



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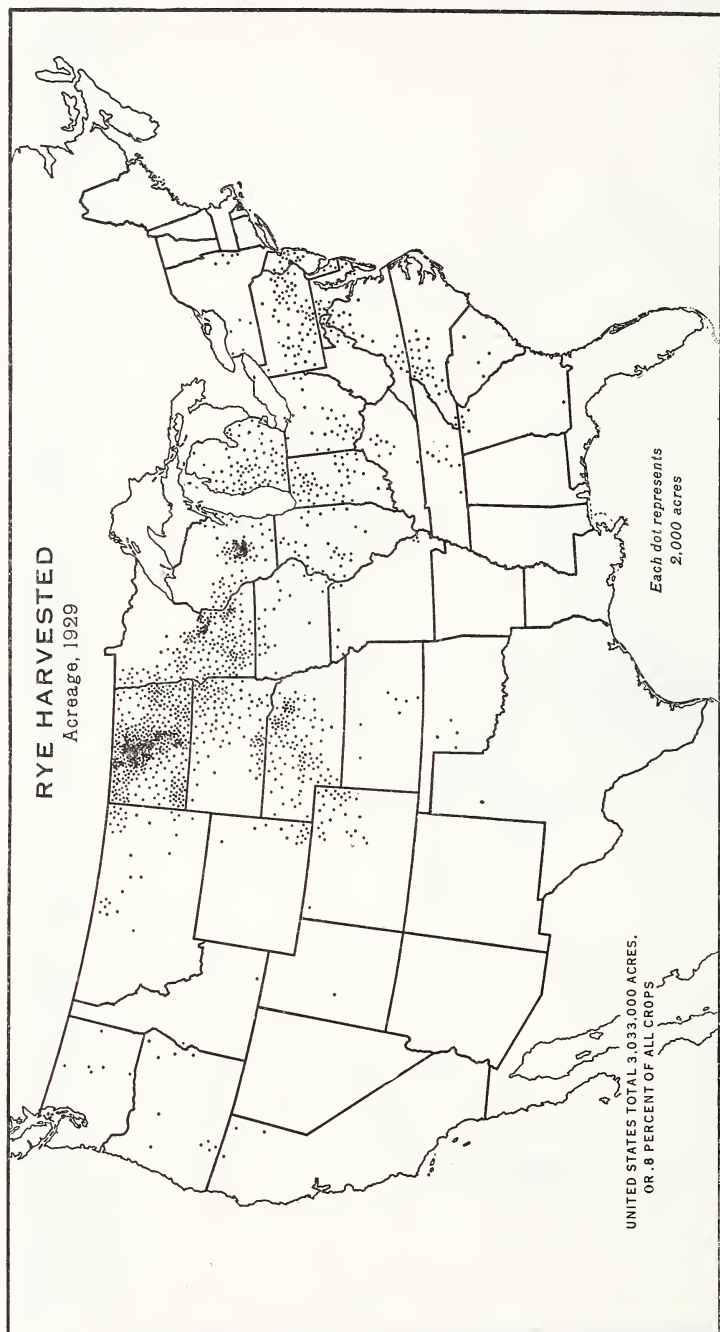
The Corn Belt, particularly the northern part, is also the center of the production of oats, and the crop is very important in the Spring Wheat and Dairy Belts to the north and east. In most crop rotations of these regions small grains—winter wheat to the south and oats to the north—are included. Oats are the principal small grain fed to livestock, and in regions of livestock and diversified farming this feed crop attains greatest importance. Oats are adapted especially to a fairly cool, moist climate. Nevertheless, a large acreage extends southwestward across Oklahoma to central Texas. This acreage, partly fall sown, is attributable more to the need of feed for horses than to favorable climatic conditions.



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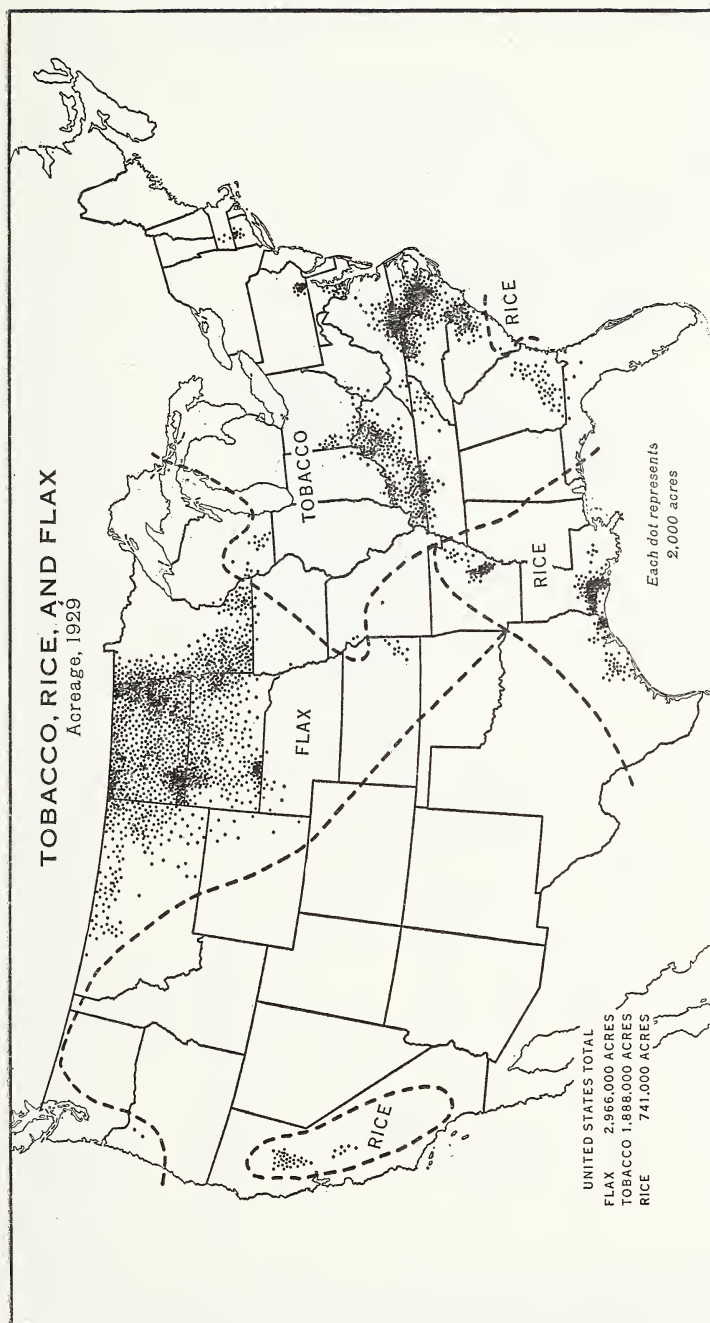
A dot on this map represents only one-fifth as much acreage as on the corresponding maps for corn, wheat, and oats. Barley is a minor crop in the United States compared with these crops, except in the Spring Wheat and Hard Winter Wheat Belts, the valleys of California, and in southeastern Minnesota, southeastern Wisconsin, and northern Illinois, where barley has persisted for a half century. Some varieties of barley are all sown in the fall in the Southwest, thus escaping most of the summer drought and heat, and largely replace corn for feed. Other varieties are cold-resistant and replace corn in the Northwest.



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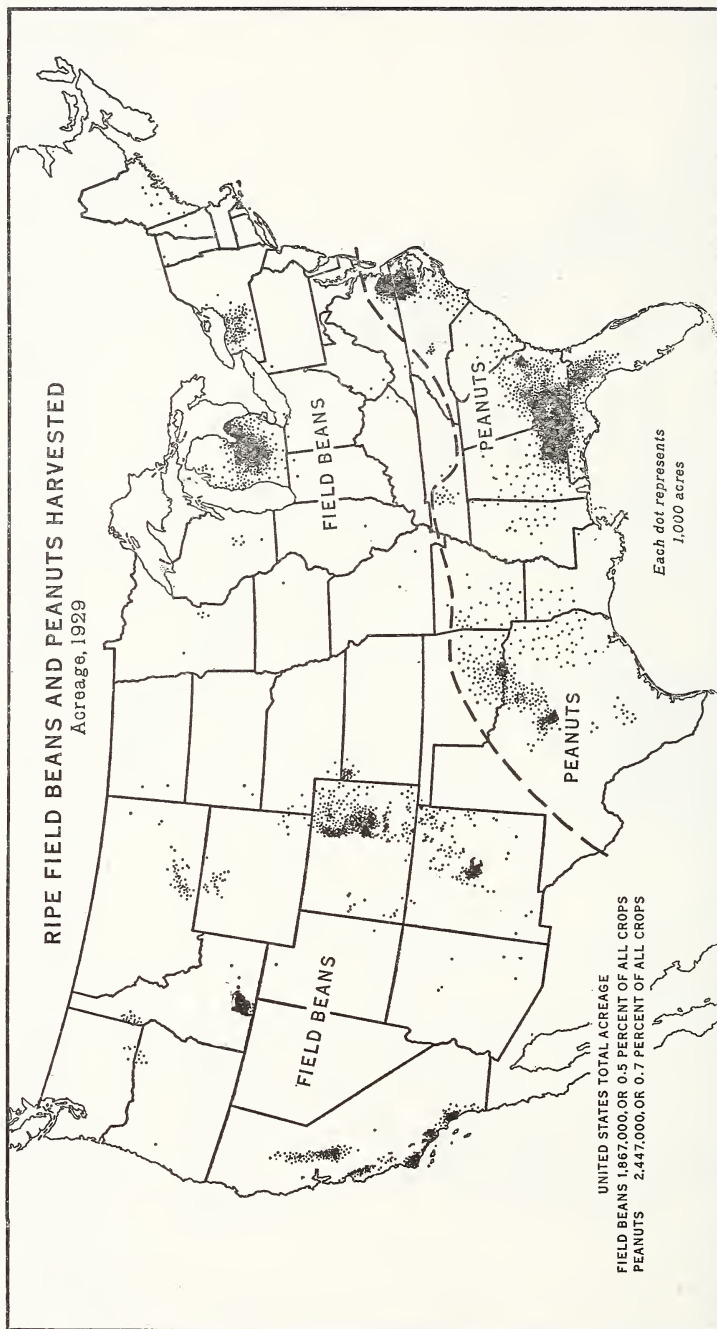
Rye is a crop peculiarly adapted to sandy or depleted soils. Before the World War it was grown principally in the sandy sections of Michigan, Wisconsin, and Minnesota, with a smaller acreage on rather poor soils in Pennsylvania, New Jersey, and eastern New York. Stimulated by high prices, production increased rapidly during the war in the Spring Wheat Belt, until by 1919 one-third of the Nation's acreage was found in North Dakota. The production of rye in western Nebraska and eastern Colorado shows that it is a very drought-resistant crop. Before the depression and the great droughts, the rye crop, like the wheat and barley crops, was shifting toward the Great Plains.



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Tobacco, rice, and flax are localized crops. Tobacco is grown mostly in Kentucky and adjacent Tennessee, in Virginia, and the Carolinas. But there are also important centers of production in southern Georgia, Maryland, Lancaster County, Pa., the Connecticut Valley, Darke County, Ohio, and southern Wisconsin. Tobacco is sensitive to soil conditions, but the requirements vary with the types. Rice is now practically confined to the coastal prairie areas of Louisiana and Texas, the prairie and adjacent lowlands of eastern Arkansas, and the valley of the Sacramento in California—all areas of heavy subsols that hold the irrigation water. Flax is grown mostly in the Spring Wheat Belt, a region of short, cool summers, in southeastern Kansas, and recently in the Imperial Valley of California in the winter.



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In western New York and central Michigan the leading varieties of field beans are White Pea, Robust, and Wells Red Kidney; on the high plains of eastern New Mexico and Colorado, mostly the native Mexican or pinto bean is grown. In California, practically the entire commercial crop of limas and a part of the crop of white beans and black-eye beans are raised; and in Idaho, Montana, and Wyoming the Great Northern, a white variety, and other varieties are grown. Peanuts for human consumption are grown mostly in the Virginia-North Carolina district between Richmond and Raleigh. Those grown in Georgia, Alabama, and Florida, in Texas and Oklahoma, are the smaller Spanish variety and are mostly fed to hogs or made into peanut butter or oil.

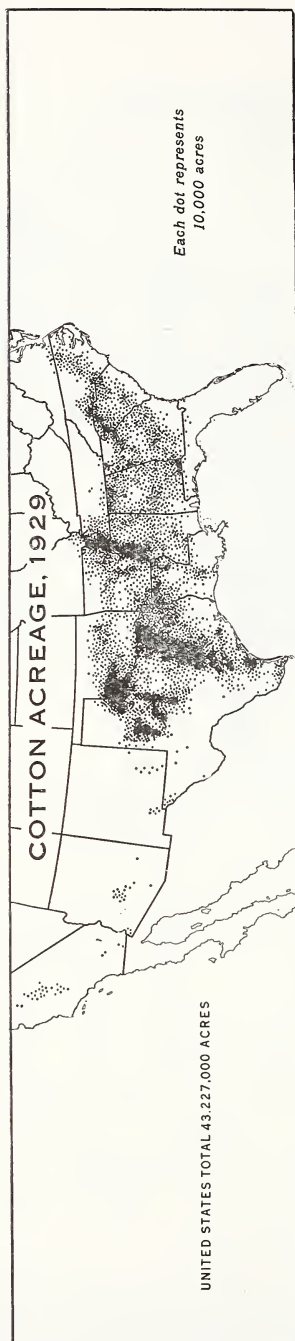
TOTAL CORN Acreage for Grain, Silage, Forage and Hogged Off, 1929

*Each dot represents
10,000 acres*

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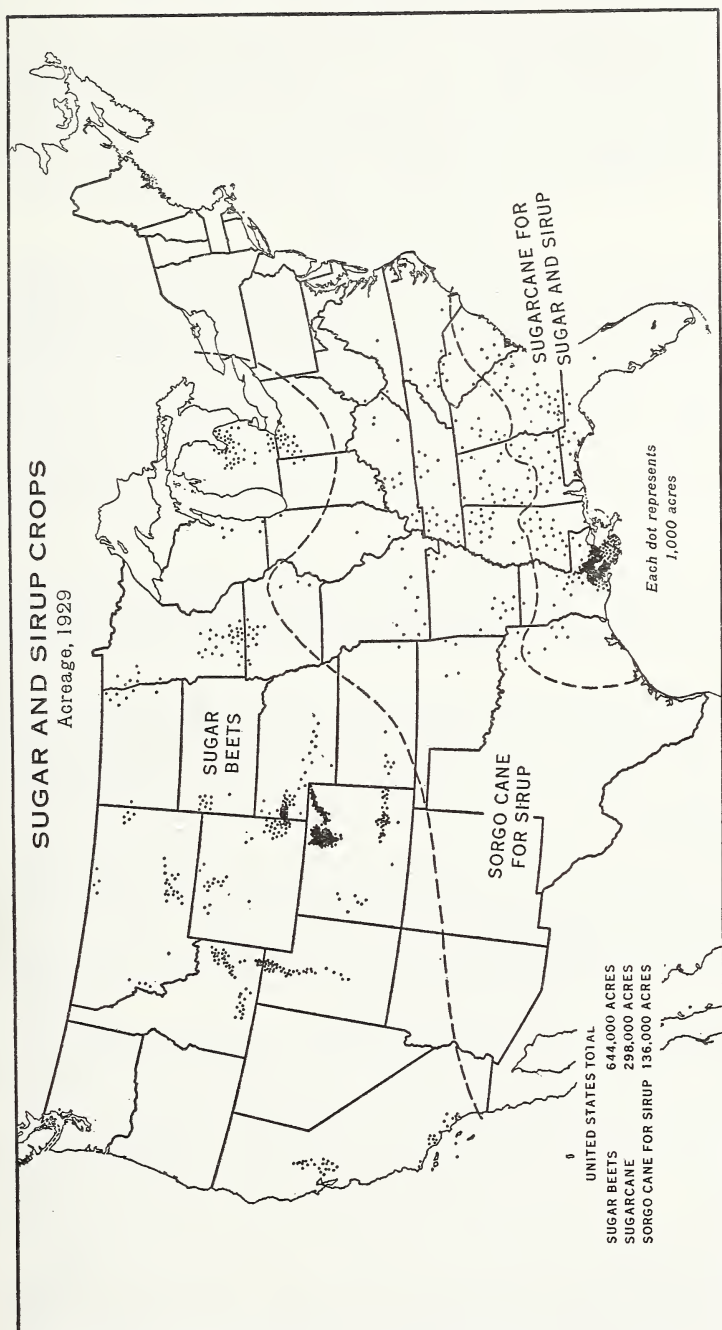
About 60 percent of the world's corn crop is grown in the United States, nearly all east of the line of 8 inches summer rainfall and south of the line of 66° F. summer temperature. In the Corn Belt, the area shown as nearly black on the map, production exceeds 3,000 bushels per square mile and in some counties rises to 5,000 bushels. This is mostly a glaciated region, much of which is characterized by prairie soil, derived principally from calcareous glacial drift and high in humus and nitrogen. The land is level to rolling, nearly all arable, and adapted to the use of modern machinery. In addition, the winters are dry and cold, retarding soil leaching, and the summers are wet and warm, promoting rapid plant growth.



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The boundaries of the Cotton Belt correspond closely on the north with the lines of 200 days of frost-free season and 77° F. summer temperature; on the south with that of 11 inches of autumnal rainfall, because wet weather interferes with picking and damages the lint, also increases boll-weevil injury. On the west the boundary is approximately 20 inches of average annual rainfall. Farther west, in southern New Mexico, Arizona, and California irrigation is necessary. The densest acreages are on the rich soils of the Yazoo delta and the prairies of Texas and Oklahoma.



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Sorgho is used to produce sirup, not sugar, and the acreage in 1920 was much smaller than in 1909 and 1919. The sirup is mostly made on the farm and only a little enters into commerce. Sugar beets do not, in general, have a sufficiently high sugar content to be manufactured profitably where the summer temperature is over 72° F; and the beets must then compete with corn for the farmer's labor. Sugarcane is now grown commercially in this country only in southern Louisiana and around Lake Okechobee, Fla.

COLLECTION AND STORAGE OF CROP BYPRODUCTS

PRESENT RESEARCH

A great deal of engineering study has been directed toward harvesting, collecting, and cleaning crops. Naturally, this work has been concerned mostly with gathering the staple crop components, such as boll contents and grain or seed. However, a limited but increasing amount of attention is being given to the collection of stalks, stems, etc., which constitute the byproduct or waste portions of the crop.

SUGGESTED RESEARCH

Probably the most important problem in connection with the utilization of agricultural wastes is their economical collection and segregation. At present, the greatest deterrent to the use of these materials industrially is the fact that there is no generally acceptable low-cost plan for local collection and concentration at convenient shipping points. Byproducts such as bagasse and oat hulls, which accumulate in large quantities at mills, create interest in their utilization because of this concentration of supply. Wastes such as cornstalks and various cereal straws, which require collection and transportation to central points, have aroused less interest. The following work has been suggested:

1. Study present harvesting methods and institute changes if practicable, so that stalks and straws may be harvested along with the main crop, thus reducing the cost of collection and preventing deterioration and loss of valuable constituents from standing in the field.

2. In order to insure year-round operation of industrial plants, these collected wastes must be stored until needed. This would require compacting into as small a space as practicable and protection from weather, insects, and chemical or biological decomposition. The following suggestions have been made in connection with problems of storage.

- (a) Studies of mechanical methods of compressing, compacting, and baling in connection with methods of shipping and the various problems of storage. Drying or pressing some wastes to remove excess water may also be important.

- (b) Studies of available equipment and design of new mechanical equipment for handling, piling, and other operations connected with the storage and use of agricultural wastes.

- (c) Investigation of methods of protection from the weather and the design of temporary or permanent structures to cover materials in storage.

- (d) Studies of physical, chemical, and biological changes occurring during storage under a wide variety of conditions. Excessive losses of valuable constituents during storage and preliminary processing are common. Methods of sterilization, chemical treatments either for the purpose of preservation or to promote desirable changes, and methods for partly processing the material to a more stable form should all receive attention.

- (e) Investigation of the economics of storage, with relation to labor costs, material losses, and transportation charges.

3. The possibility of completely processing agricultural wastes on the farm at the time of harvesting the basic crop, either in the same or in a separate operation, should be studied. In considering such operation, storage, and marketing of the processed byproducts should receive careful attention.

FUNDAMENTAL STUDIES

GENERAL AND BIOCHEMICAL STUDIES

PRESENT RESEARCH

Some fundamental research is in progress on the biochemistry of the principal constituents of agricultural wastes, on photosynthesis in plants, and on the effects of soil and cultural and climatic conditions on the composition of plants. Some crop plants have been studied with regard to the quantity and quality of lignin present at various stages of growth. Investigations have been made on the role of cellulose and lignin in the metabolism of farm animals. Studies have been made on the cellulose content of various crop wastes and on methods for its determination. Attention has also been given to some of the minor constituents of certain crop wastes and wild plants.

SUGGESTED RESEARCH

There is a definite need for more fundamental information on the chemical composition of the various agricultural wastes and on the structure of individual components. The research projects suggested are:

1. The conditions of growth (climate, soil, etc.) and the relation of these factors to variations in content of the principal components, such as cellulose, hemicelluloses, and lignin, as well as of the minor constituents.

2. The mechanism by means of which certain inorganic components are stored in the plant structure, for example, the high percentage of silica in rice hulls.

3. The relation of conditions of growth (climate, soil, etc.) to the general structure of stalks, stems, cobs, etc. Pertinent information on this subject might furnish a means for providing sources for fibers, pulps, or other products with certain definite, desirable characteristics. (See also the section on Fundamental Cellulose Research under Fiber Crops.)

4. Components are present in small amounts about which some information is available, such as the wax on sugarcane stalks. These components should receive additional study, and methods for recovery should be worked out where uses for the materials can be demonstrated to be economically desirable. The possibility of producing varieties having a larger content of desirable components should also be studied.

STUDIES ON LIGNIN

Lignin, one of the chief constituents of plants, is a complex chemical compound consisting essentially of either aromatic units (benzene derivatives) or potentially aromatic units. With the exception of coal, lignin is the only large natural source of aromatic compounds.

When our coal deposits are depleted, if not before, lignin will necessarily be employed to supply the huge industrial demands for aromatic compounds. As a component of farm wastes, lignin is produced in this country to the extent of about 45 million tons annually. In addition, several million tons are burned or are discharged as liquid wastes from wood-pulp mills.

Although lignin has potentialities comparable with those inherent in coal tar a century ago, not much success has attended the search for methods of utilizing it industrially either as such or in the form abundantly available as waste sulfite liquor from pulp mills. Nevertheless, because of the cheapness of raw materials and the tremendous quantities available, the possible industrial utilization of lignin is still the object of considerable interest. Perhaps the main barrier to the successful solution of this problem is inadequate knowledge regarding its isolation, composition, and structure, as well as the lack of means for its economical conversion to materials having useful properties. The modified lignin dissolved from wood in the kraft and soda processes of pulp manufacture is invariably burned in the process of recovering the pulping chemicals, and there is some prospect of developing a type of sulfite process which would likewise utilize the lignin as fuel. In recent years lignin has received attention as a raw material for the plastic industries and, in the form of sulfite liquor, as a source of vanillin, so-called because it is the chief odorous ingredient of the vanilla bean. In addition to its use as a synthetic flavoring material, vanillin is useful in other chemical industries.

PRESENT RESEARCH

Current research on lignin is scattered and suffers from a lack of coordination. The work may be conveniently broken down into two classes—fundamental studies and applied studies. Specific investigations are:

Fundamental studies.

1. Chemical, physical, and biological studies of lignin from various sources such as wood, straws, and nutshells, with the aim of determining its constitution and its mode of occurrence and physiologic function in plant tissue. (See also the section on Forest Products.)
2. Studies on the biogenesis of lignin to ascertain the successive steps and the complicated reactions involved in its synthesis and deposition in the tissues of the plant.
3. Relation to the absorption of minerals by plants. Studies designed to show the relation between lignin as a component of humus and the base-exchange properties of soil are being carried out.
4. Investigations to determine the role played by lignin in fermentations and in the formation of soil humus. Lignin is considered one of the main precursors of soil organic matter.
5. Relation of lignin in cereal straws to lodging. Plants become brittle as the lignin content rises, and their ability to resume an upright position when storm-blown is lost.
6. Studies on geophysical heating in an attempt to show that lignin is the source material for coal and petroleum.
7. Degradation by chemical procedures for production of alcohols, aromatics, hydroaromatics, and other compounds (hydrogenolysis).

Applied studies.

8. Hydrolysis of farm wastes to produce lignin as a raw material for other processes. Isolation of the byproduct sugars is being concomitantly studied.

9. Investigation of the economic problems involved in using lignin to remove iron from water. Iron can be successfully eliminated in this manner, and the economic phases of the problem are being weighed.

10. Processing lignin into plastics suitable for structural purposes. This field in particular is under extensive investigation. (See Plastics in this section.)

11. Chemical treatment to liberate vanillin and other aromatic compounds. A commercial process for recovering vanillin from waste sulfite liquor has recently been introduced.

12. Modification of lignin in waste sulfite liquor for production of materials useful as tanning agents, core binders, road binders, dust settlers, adhesives, dye diluents, and preservatives.

13. Ammoniation of waste sulfite liquor for the production of organic nitrogenous fertilizers.

SUGGESTED RESEARCH

An active and coordinated program, aimed at lessening the difficulty of preparing lignin and elucidating its chemical composition, is urgently needed to provide a firm basis for carrying out further studies on the utilization problem. Suggested investigations are:

1. Development of economical methods for preparing lignin from various farm wastes. Little is known of the production cost of lignin in forms suitable for industrial utilization.

2. Further fundamental investigations on the constitution of lignin, using recently devised physical and chemical research methods. Many investigators have attacked this problem in the past, but knowledge of the structure of lignin is still incomplete.

3. Conversion of lignin to plastic materials. An outlet for large quantities of lignin would be provided by this type of industrial development if practical and economic difficulties could be overcome. (See Plastics, in this section.)

4. Modification of lignin by chemical methods, such as chlorination and nitration, for conversion to materials having properties suitable for new industrial uses, such as adhesives and antiwetting agents. Many chemical derivatives of lignin have been formed, but so far no serious attempt has been made to commercialize them.

5. Development of lignin as a source of raw material for the production of such aromatic compounds as phenol, cresol, guaiacol, protocatechuic acid, and vanillin, which are useful as bases for plastics, insecticides, preservatives, etc. Attempts to solve this problem, save for the preparation of vanillin, have thus far met with failure.

6. Degradation of lignin or modified lignin by various processes, such as oxidation and reduction, into simpler units for application in the processing industries.

7. Investigation of the decomposition of lignin in the soil. The relation between lignin and soil humus should be studied, as well as the base-exchange characteristics of lignin in terms of growth response. (See also Composting in this section.)

8. The use of lignin or its derivatives as a size or filler in the textile or other industries.

STUDIES ON HEMICELLULOSES (PENTOSANS AND HEXOSANS) AND DERIVATIVES

Hemicelluloses and related material constitute from 20 to 35 percent of the dry matter of wastes such as oat and rice hulls, cottonseed hulls, bagasse, cereal straws, and corncobs. Since the annual tonnage of localized sources of the foregoing waste items alone approximates 5,000,000—this figure includes no cereal straws and only those corncobs collected at mills—it is apparent that large sources for hemicellulose or derived materials are available for industrial exploitation. Two lines of attack have been pursued in developing industrial uses for hemicelluloses: (1) Mild mineral acid hydrolysis for the production of xylose, and (2) chemical treatment to produce furfural. The quantity of farm waste thus used, however, is only a fraction of a percent of that available.

Hemicelluloses are complicated bodies in which the simplest units are either sugars or sugars and sugar acids. The percentage of sugar acids present is generally quite small. Little information is available either on the constitution and properties of hemicelluloses or on economical methods of preparing them; they have received much less attention than any of the other predominant natural plant products. At present they are not employed commercially as such, and the development of industrial uses no doubt has been handicapped by lack of precise chemical data concerning them. The meager information available indicates that their properties not only are quite different from those of lignin, proteins, cellulose, fats, etc., but also are of such a kind as to suggest the possible wide utilization of these materials, after suitable modification, for novel industrial uses.

XYLOSE, ARABINOSE, AND URONIC ACIDS

Xylose, arabinose, and uronic acids are hydrolysis products of hemicellulose and related materials. Xylose, which usually predominates, is a pentose sugar and has attracted considerable attention in the past, chiefly because of the tremendous quantities potentially available in cheap raw materials. In the early part of this decade considerable work was done in both private and public institutions with the aim of investigating its possible industrial uses. Methods were developed for preparing pure xylose from cottonseed-hull bran. Engineering difficulties were largely surmounted, and its price was reduced to about 25 cents a pound. The anticipated extensive uses for the product turned out to be disappointingly small, however, and as a result commercial exploitation of this material practically ceased. This picture might possibly change if the cost of production could be reduced to that approximating the other commercially available sugars. Arabinose and uronic acids may be obtained in rather large amounts from some materials related to hemicellulose. The study of this problem and the possible industrial utilization of these products have received practically no attention.

FURFURAL

Furfural is derived from the pentose and uronic acid of hemicellulose and related materials by removal of chemically combined water and conversion to an oxygen-containing, ring-shaped compound. This

compound contains an active group, which is responsible for its most useful properties. At present furfural is being produced commercially from oat hulls, which are available in large quantities as a byproduct in the manufacture of rolled oats. Major difficulties in the production of furfural have been overcome, and the resulting cheapness of the material, in part at least, has led to three important uses: (1) In the manufacture of synthetic resins; (2) in the purification of wood rosin; and (3) in refining lubricating oils. Additional uses based on the paint-removing, solvent, and preservative properties of furfural are being evaluated.

PRESENT RESEARCH

Hemicelluloses and related material.

Investigations in the field of hemicelluloses are scattered and limited, the least emphasis being placed on industrial utilization. Some work is of a negative character and has therefore not been treated here—for example, research on removal of hemicellulose as an impurity from cellulose without injuring the latter. Most of the following pertinent research is being carried out in public institutions.

1. Investigation of hemicellulose in relation to the chemical composition of wood. (See also Forest Products.)

2. Preparation of hemicelluloses from cottonseed hulls, oat hulls, etc., and hydrolysis to simpler units.

3. Separation of hemicellulose from cereal straws, hays, and other forage crops and hydrolysis to sugars and sugar acids. This project, which is of recent origin, has as its objects the determination of the chemical constitution of hemicelluloses, their genetic relationship to other plant constituents, and the nature of their decomposition products formed during storage.

4. Chemical utilization of pentosan-containing materials.

5. Research on the function of hemicelluloses in paper making.

Xylose, arabinose, and uronic acids.

Work now being done on xylose, arabinose, and uronic acids is fundamental research along the lines described in Fundamental Studies on Sugars under Sugar Plants. Studies under way with the aim of finding specific uses for xylose are as follows:

6. Fermentation of xylose by various micro-organisms to form new types of products of industrial interest. Thus far these investigations have not led to the discovery of novel derivatives.

7. Oxidation by various methods to produce xylonic acid, for which uses have yet to be developed.

Furfural.

In addition to a continuation of research directed along the lines of the uses indicated for furfural, current investigations deal with:

8. Production of furfural from waste sources other than oat hulls.

9. Modification of furfural to produce a number of compounds suited to industrial utilization. Furfuryl alcohol, tetrahydrofurfuryl alcohol, etc., are being prepared commercially from furfural and appear to have promise as solvents, plasticizers, and wetting and cleansing agents.

10. Use of furfural and its resinous derivatives to improve wetting power and adhesiveness of bitumen for mineral aggregates and soil in low-cost road construction. The results promise largely increased use of furfural.

11. Fundamental chemical investigations on furfural and its derivatives. This field is under broad active investigation and includes studies on reduction, conversion to nitrogen- and oxygen-ring compounds, modification to acyclic aliphatic compounds, etc.

SUGGESTED RESEARCH

Hemicelluloses and related material.

In the exploitation of hemicelluloses a comprehensive program would be required to secure the necessary fundamental and engineering data. This would involve:

1. Isolation and comparison of hemicelluloses from different kinds of wastes. Hemicelluloses and some other sources may have more valuable characteristics than those so far investigated.

2. Purification and fractionation of hemicellulose and related materials to obtain homogeneous products. This preliminary work will insure reproducibility of data and facilitate studies on composition.

3. Characterization and constitutional studies, applying chemical and physicochemical methods. Results obtained will suggest various rational attacks on the utilization problem. (See also the section on Cellulose under cotton and Other Fiber Crops.)

4. Investigation of the chemical properties of hemicelluloses. New derivatives should be prepared, with emphasis on mild oxidation and those reactions, such as acetylation, methylation, and nitration, which yield products having about the same molecular complexity as the original material. This type of derivative may be peculiarly adapted to the plastics and artificial fiber industries. Methods effecting a controlled stepwise resolution of hemicellulose to simpler units would afford means for securing new types of interesting products.

5. Development of methods for preparing hemicelluloses and related materials in a form suitable for industrial utilization. This work would include both small-scale and pilot-plant studies on old and, in particular, on new processes for hemicellulose production and would serve as a basis for arriving at the approximate cost of manufacture. These products would be potentially useful if they could be prepared for about 3 cents a pound.

Xylose, arabinose, and uronic acids.

6. Development of cheaper methods for isolating xylose.

7. Investigation of uses for the byproduct sirups obtained in xylose manufacture. Success in this direction would help to lower the cost of xylose production. Possible utilization of these sirups as feeds or in the fermentation and tanning industries is suggested.

8. Search for new uses for xylose.

9. Fundamental chemical studies, including modification of xylose to derivatives of possible industrial interest as, for example, hydrogenation to xylitol.

10. Investigations on the yields of arabinose and uronic acid from hemicelluloses and related materials. Discovery of rich sources of these products should be followed by studies similar to those outlined for xylose.

Furfural.

11. Production of furfural from agricultural wastes, especially straws from wheat and other grains.

12. Development of new methods for converting furfural into improved plastic materials. At present plastics made from furfural suffer from the disadvantage of being dark colored. (See also Plastics in this section.)

13. Practical investigations to find new uses for furfural and its derivatives. Employment of furfural as a source of power for Diesel engines has been suggested; however, at present price levels (about 9 cents a pound) furfural cannot compete with the common fuel oils.

14. Fundamental studies on the chemical processing of furfural, including hydrogenation (with the aim of producing polymethyleneglycols having possible use in the plastic industries, or long-chained alcohols of possible value in the detergent industries), conversion by appropriate chemical treatment to unsaturated fatty acids that might prove useful to the paint and varnish industries, and modification to nitrogen-ring compounds for possible utilization as insecticides.

UTILIZATION OF CROP BYPRODUCTS

COMPOSTING

Composting farm wastes for the production of artificial manure is essentially a biological or fermentation process. The lignin, cellulose, and particularly the hemicellulose constituents of farm wastes are partially available as sources of energy for micro-organisms and practically available for conversion to humus. The small amount of protein is changed to simple nitrogen compounds and to bacterial and mold protein. Preparation of composts can be controlled to yield materials valuable mainly for their humus content or for both mineral and humus content. For the latter purpose the liberal addition of minerals during the composting process would be necessary. In soils rich in plant nutrients composts would be employed mainly for their humus content, whereas in impoverished soils composts fortified with minerals would be required.

Considerable research work and vigorous educational campaigns on the value of composting waste material have been conducted in certain parts of the world, for example, Europe, South Africa, and India, where soils either are low in organic matter or have been intensively cultivated for centuries. In contrast, very little research or educational work on the production of manures has been carried out in the United States, where only in recent years have there arisen a consciousness of and alarm at the rate at which our soil is being destroyed.

PRESENT RESEARCH

In addition to the practical type of composting carried on at some farms, some study is being devoted to this problem at the State experiment stations. Investigations having only an indirect bearing on composting, as for example, fundamental studies on nitrogen-fixing organisms, are not included here. Studies now under way are:

1. Investigations conducted on the use in composting of agricultural materials, such as straw; alfalfa roots and tops; sweetclover bloom, roots, and tops; corn stover; and leaves.

2. Investigations on the microbiological aspects of the decomposition of plant materials, the break-down of isolated plant cellulose by cellulose-decomposing organisms, such as fungi and bacteria, and the decomposition of lignin in soil.

3. Studies on the treatment of straw left by the combine with the object of making it an effective artificial manure and thus preventing detrimental effects upon succeeding crops.

SUGGESTED RESEARCH

The many suggestions made for research on the industrial utilization of farm wastes envision possibilities for considerable diversion of these fibrous materials to industrial channels. This development will take place slowly, no matter what eventual quantities are consumed. On the other hand, for any given soil there is a minimum amount of organic matter that should be supplied annually, probably in the form of composted or similarly treated materials, if satisfactory fertility and productivity are to be maintained. It is apparent, therefore, that research on composting is urgently needed and that it should be continuous. For satisfactory soil management large annual amounts of organic material will always be needed, and it is safe to assume that many farm lands, particularly in the South, are now more urgently in need of such material than they would be after a period of sound management. Development of a satisfactory composting technique should therefore receive primary consideration. Under no circumstances and at no time should industrial utilization of farm wastes be carried to the point of permanently robbing the soil of necessary organic constituents. Each crop should pay its debt to the soil. Suggested studies comprise:

1. Pilot-plant operations, especially to develop mechanical appliances to handle and mix farm wastes, and chemicals to process and deliver a finished product suitable for direct application to the soil. The kind and type of microbiological population best suited to production of artificial manures, including liquid manures, require investigation. The optimum microbiological and chemical environment for reducing the constituents of farm wastes to humus materials should be determined, and optimum conditions of time, temperature, moisture, hydrogen-ion concentration, and oxygen studied. The advisability of reinforcing the artificial manures with inorganic fertilizers, particularly for the southern and eastern sections of the country, should be considered. The fertilizing value of the artificial manures should be determined by agronomic experiments. A successful process should also be applicable to the simultaneous utilization of sludge and garbage from urban communities.

2. Small-scale composting by bin, trench, and sheet methods. Different types of farm wastes should be composted by these various methods and the results compared, particularly from the standpoint of time required, cost, and the value of the final products in terms of crop response. The general type of study would be quite similar to that outlined for the pilot-plant operations.

3. Direct utilization in the soil of crop residue (and green crops), with or without the simultaneous use of fertilizer, as sources of soil organic matter. The most efficient and practicable method of utilizing cereal straws, corn stover, corncobs, and other sources of organic matter of varying carbon-nitrogen ratios in the maintenance of soil

organic matter under different climatic conditions and in various types of soil should be determined. The value of the different farm wastes as sources of energy for free-living, nitrogen-fixing bacteria and the extent to which these materials act as indirect sources of nitrogen through their stimulation of nitrogen fixation in soils should be considered. Work should also be done on the efficient introduction of wastes into the soil by means of mechanical appliances.

4. Fundamental investigations on the biological and chemical changes occurring under the different systems of composting and in soils to which various types of organic matter have been added under different soil and climatic conditions. The role played by the different micro-organisms or symbiotic combinations of them in converting the cellulose, lignin, and hemicellulose into humus, and the optimum conditions for effecting these changes, should be studied. Information on the relative importance of cellulose, hemicellulose, and lignin as humus formers should be secured, as it would be of considerable importance in the restoration of organic matter to the soil and in the intelligent utilization of these materials. Studies on the composition of the various kinds of humus and plant nutrients formed under different biological conditions should be carried out. Possible decomposition or synthesis of plant-growth hormones under composting conditions seems worthy of attention.

BUILDING AND INSULATING MATERIALS

PRESENT RESEARCH

Many of the fibrous agricultural wastes are being studied with a view to their utilization in the production of wallboard, structural insulation, and other building materials. The work is directed mainly toward the utilization of bagasse, straws, and cornstalks, although other wastes are being studied. In spite of the extensive work that has been done, many problems are still unsolved. The principal subjects of current research are as follows:

1. Problems of production concerning various forms in which the material is used—sheets, blocks, bats, fills, etc. These are probably receiving major attention.

2. The improvement of structural properties, such as strength, stiffness, and hardness.

3. The utilitarian properties of thermal conductivity, sound absorption, etc.

4. Other work directed toward the development of various decorative finishes, shapes, and uses.

5. Treatment which will develop special properties, such as water resistance, fire resistance, and resistance to decay and insect attack.

6. The relationship of the form of the insulation material (sheet, block, bat, fill, etc.) to the various properties. This is under investigation by a number of agencies.

SUGGESTED RESEARCH

Much of the technology of the wallboard and structural insulation industry has been developed empirically, and although many problems have been solved there is room for much basic research dealing with a number of essential factors. Subjects suggested for study are:

1. The effect of individual fiber characteristics—length, strength, flexibility, smoothness, felting ability, etc.—upon the strength, stiff-

ness, hardness, and other structural properties. (See also the section of Cellulose under Cotton and Other Fiber Crops.)

2. Methods of aggregation, such as felting, forming, and molding, and the effects of processing, such as cooking and refining, upon the strength, stiffness, hardness, and other structural properties. These studies, should of course, include methods of preparation of the fiber as well as the influence of agronomic varieties and conditions of growth, harvesting, and storage. (See also Pulping.)

3. The relationship of thermal conductivity to density, fiber size, structure, form, etc. Under thermal conductivity, studies also should be included to determine the effect of various binders used in the block type of insulation, as well as the effects of packing, vibration, and settling on the bat and fill types.

4. A similar study correlating acoustic properties, such as sound absorption and transmission, with density, fiber size, structure, form, etc.

5. An investigation of treatments for waterproofing or imparting vapor resistance and their influence on the physical properties of building and insulating materials, especially as they affect the structural applications. This study should include the effect of moisture on physical properties.

6. Development of methods for fireproofing fiber insulating materials. One of the limiting factors in the use of fiber insulating materials is lack of resistance to fire. This feature should receive concerted attention in order to develop chemical methods of treatment as well as methods involving mixtures with inorganic or inert binders. This study should also include the effect of these treatments on physical properties.

7. Protection of insulating materials from decay and insect attack. Damage to cellulosic materials due to termite attack is prevalent throughout a large part of the United States, and losses due to dry rot and various other forms of decay are practically as widespread.

8. Development of new structural shapes and products, such as floor, wall, and roofing tiles, shingles, and siding, and finishes and treatments to provide special properties for specific uses.

9. Investigation of the toxic effects of any proposed or developed treatments.

10. Simple processing to make building materials on farms, for use in rural areas.

11. Investigation of the possible use of straws or other agricultural wastes in connection with nonagricultural materials to produce structural products such as adobe.

PULPING

PRESENT RESEARCH

Current studies on pulping can be divided for discussion into two groups. In studies of the first group efforts are being directed largely toward the production of utilizable pulps for paper, board, or similar uses. In those of the second group efforts are being directed toward the production of highly purified cellulose for use as a raw material for cellulose derivatives, such as cellulose acetate, cellulose nitrate, and rayon. In other words, one group concerns the production of fibers to be used as such, and the other concerns the production of purified

cellulose to be used chemically. (For closely related work in other fields, see the sections on Forest Products and Fiber Crops.)

Perhaps the most extensive work on pulping of agricultural wastes for paper or board has been carried on with straws. Considerable work has also been done on cornstalks because of the immense tonnage produced and on bagasse because its concentration at sugar mills eliminates cost of collection. The work on straws has been directed toward the production of the cheaper types of paper and board.

The production of strawboard and straw-containing board amounts roughly to 25 percent of the total production of paperboard, or 11 percent of the total of paper and board. In 1935 the production of straw-containing board totaled more than 1,000,000 tons, valued at more than \$39,000,000. These figures show clearly the possibilities for research along these lines. Studies on the utilization of cornstalks and bagasse for paper making have been directed mainly toward the production of book and writing papers because of specific characteristics of the fiber. Some research work has been done on pulping stalks of cotton plants, asparagus, and celery, grapevine trimmings, and other plant wastes.

All the usual pulping procedures have been studied at one time or another, the research having as its object mainly the adaptation of some familiar process to the particular waste under investigation.

At present the nitric acid process for the production of alpha-cellulose from agricultural wastes is receiving considerable attention. In this process the material is treated at atmospheric pressure with low concentrations of pulping agents, which conditions are desirable in view of the bulky nature of agricultural wastes and the necessity for using large volumes of pulping liquors. Research work is also being done on other pulping procedures, including the soda, sulfite, sulfate, and ammonia processes and modifications using chlorine.

SUGGESTED RESEARCH

In spite of the substantial amount of current work, the problems of pulping are far from solved. Satisfactory pulps have been produced experimentally but have not reached competitive commercial production. The following studies on pulping have been suggested:

1. The nitric acid process for pulping agricultural wastes. This is essentially a two-stage process in which the preliminary treatment with dilute nitric acid is followed by an alkaline cook with caustic soda. The success of this process will depend largely upon the cost at which nitric acid can be obtained as well as upon improvements in the process. Present developments in nitric acid production point toward lower prices. A study should be made of the action of other agents in connection with this process, such as alcohols and urea, or combinations that will promote or control the action of the nitric acid.

2. The use of volatile alkaline compounds, such as ammonia, for pulping. This process envisions recovery of the lignin and also recovery and reuse of the pulping agent. It should be studied with the idea of producing paper pulp as well as alpha-cellulose.

3. A fundamental study of all the known solvents for the principal constituents of agricultural wastes—cellulose, hemicelluloses, and lignin. From this fundamental study it may be possible to develop

a pulping procedure that will be particularly adaptable to agricultural waste materials.

4. Methods for the direct solution of the cellulose of agricultural wastes and its regeneration or conversion to useful cellulose compounds.

5. Study of the apparatus and equipment for use in any of the pulping processes investigated or developed. Problems of corrosion and of handling materials, and multitudinous chemical engineering problems will have to be solved. These problems will assume greater importance as preliminary investigations are enlarged or pilot-plant work is begun.

6. Studies to adapt present manufacturing processes to fibers and pulps from agricultural wastes. It is quite likely that the fibers and pulps produced from agricultural wastes may differ in one or more characteristics from the fibers and pulps now used. This project should include studies on paper and board forming, drying, waterproofing, sizing, finishing, coloring, and laminating; on machine methods and materials; and on the use of fillers and binders. Work on acetylation, nitration, esterification, and other chemical treatments of cellulose is needed. (This is more fully discussed in the section on Cellulose under Cotton and Other Fiber Crops.)

7. Study of the constituents of waste liquors from the different pulping processes, with a view to their utilization. (For special consideration of these projects refer to the section dealing specifically with lignin and hemicelluloses in this section.)

FERMENTATION

PRESENT RESEARCH

In the natural processes of decay biochemical action plays an important role. This is nature's way of reducing the products of growth to simpler units for use in the growth of succeeding crops. Research projects under way in this field are:

1. The production of gases by the anaerobic (thermophilic, mesophilic, etc.) break-down of fibrous agricultural wastes. These gases contain considerable quantities of methane, hydrogen, and carbon dioxide and have a calorific value high enough to make them useful as fuel. These anaerobic processes have not yet been developed sufficiently to enable the farmer to make his own fuel gas economically. As in all processes based on the action of micro-organisms, conditions must be carefully controlled, the proper nutrients for growth must be supplied, and retarding or interfering influences must be eliminated.

2. Studies to produce pulps or other utilizable residues by means of anaerobic fermentation. These have not been successful because the cellulose and hemicelluloses of the wastes are attacked more readily than the lignin portions. Hence, the principal purpose of the study has not been realized.

SUGGESTED RESEARCH

The following studies have been suggested:

1. Investigations on conditions necessary for the production of gases of optimum fuel value. Current research on the production of fuel gas should be continued and expanded.

2. Investigation on the factors controlling variations in the ratios of the different gases produced. It would probably be desirable at times to produce increased percentages of one or more components at the expense of the others, and if the conditions favoring the desired results were known the process would have greater value.

3. Exhaustive studies to determine whether products can be made which are different from those made at present. This possibility would increase interest in the process.

4. A study of organisms or groups of organisms other than those now used in an effort to find strains that will be able to act more efficiently, require less control or supervision, or need less fermentation time.

5. Investigation of the possible use of the gaseous products of fermentation for other than fuel purposes.

6. Investigation of the residues from these fermentations as a possible source of lignin.

PLASTICS

PRESENT RESEARCH

Current research on plastics from agricultural wastes is a parallel development of recent work on wood wastes. The methods used in that research have been found particularly adaptable to work on agricultural wastes. A limited amount of work is now in progress on the more promising leads in this field. This research consists of—

1. A study of methods of acid hydrolysis of agricultural wastes, followed by washing, drying, and powdering the hydrolyzed material and mixing it with chemicals such as aromatic amines and aldehydes. Practically no theoretical or fundamental work has been done.

2. Limited studies on the development of the molding and curing technique by empirical methods.

3. Exploratory work on materials suitable for plasticizers.

4. Studies of other methods of hydrolysis, such as alkaline treatments. Processing with chemicals, such as phenol, aniline, and furfural, instead of hydrolysis, is also receiving attention.

5. A study of the effect on molding behavior and strength of the addition of lignin to hydrolyzed agricultural wastes.

6. Studies on lignin itself, in addition to the work on lignin-containing materials, with the idea of using it to produce plastics. (See p. 63 of this section.)

SUGGESTED RESEARCH

A low-cost plastic molding powder would provide an outlet for large quantities of agricultural wastes. It would find use in the production of building materials such as floor, roof, and wall tiles, shingles, and siding, and possibly in furniture parts and other articles. The following studies on this project have been suggested:

1. Fundamental research on the chemical reaction that occurs when hydrolyzed fibrous materials are molded in the presence of aromatic amines, aldehydes, and other chemicals which cause or promote plastic formation.

2. A contemporary and related study on plasticizing agents and methods.

3. Fundamental studies (based on the findings under (1) and (2)) on the agricultural wastes in order to develop methods for producing the modifications found to produce the best molding powders.

4. A study of other methods of hydrolysis and other chemical methods of treating the wastes for the purpose of improving the structural and decorative properties of the plastics and lowering the cost of the finished articles to the consumer.

5. The development of molding processes which would lend themselves to efficient production methods so that the low cost of the raw material would not be offset by excessive fabrication costs.

6. Studies on lignin plastics. Although lignin is an important component of plastics made from hydrolyzed fibrous wastes, concurrent research, similar to the aforementioned, should be conducted on lignin plastics themselves. (See Lignin, in this section.)

7. Studies on molding compounds from hydrolyzed or otherwise treated fibrous wastes to which lignin derived as a byproduct from other processes has been added.

8. Studies to develop means for widening the temperature range at which flow occurs or for slowing down the setting, which in most of the materials so far investigated takes place too soon after the molding material becomes fluid.

DESTRUCTIVE DISTILLATION

PRESENT RESEARCH

The destructive distillation of wood has been carried on for many years. At one time it was practically the only method for producing certain products, notably methanol or wood alcohol. As a result of the introduction of synthetic methanol and economic conditions affecting the industry, many of the wood-distillation plants have been closed. This situation has not encouraged research work on the destructive distillation of agricultural products, which would naturally supply products similar to those derived from wood.

However, some studies have recently been made on the production of gaseous fuels, chemicals, oils, tars, solvents, and carbon residues by pyrolysis of agricultural wastes. The products have greater value than the original wastes, and they are in better form for commercial uses.

SUGGESTED RESEARCH

Some of the lines of research that should be followed in a study of the pyrolysis of agricultural wastes are as follows:

1. Fundamental work on the effects on yields of different products of changes in the conditions of destructive distillation, including temperature, pressure, and composition of the gases in the pyrolysis zone.

2. Investigation of various combinations of conditions to produce definite end products, for example, (1) certain products that may be in demand at a particular time; (2) Diesel-type fuels; (3) denaturants for alcohol for use in motor fuels; (4) constituents isolated in fundamental studies.

3. Fundamental chemical study of the usual pyrolysis products to produce modifications of increased value, as by hydrogenation of the gases.

4. Research to design more efficient or more definitely controllable equipment for destructive distillation. The transfer of heat and control of temperature are always difficult with materials of this sort, since they are normally good heat insulators.

5. Research on the production of new types of liquid fuel. Consideration should be given to the redesigning of internal-combustion engines to permit most efficient use of the new fuel. Knock characteristics, gumming properties, etc., both of the fuels alone and of blends with gasoline and heavier petroleum distillates, should be studied.

MISCELLANEOUS USES

Interest in the miscellaneous uses of agricultural wastes has centered about outlets in which the wastes are used as such or in which very little modification is necessary. These include the more or less obvious uses, some of which have been developed recently while others have been inherited from our ancestors.

PRESENT RESEARCH

There has been active interest in other uses for wastes. In many of these fields some investigation is actively under way; in others there have been only superficial trials. These uses are: Fillers for plastics and rubber; briquetted fuels; poultry litter and animal bedding; carriers and diluents for poisons in the preparation of insecticidal dusts; agricultural mulch; and uses for water-soluble and other extractives; other miscellaneous uses, such as absorbent for nitroglycerine in the manufacture of dynamite, moisture retarder in the curing of concrete roads, and many similar uses.

SUGGESTED RESEARCH

Some lines of research on miscellaneous uses of agricultural waste materials might prove profitable for example, uses for such materials in finely divided or flourlike form. Some of these uses would require only relatively small quantities of materials, but a number of such small items might add up to an impressive total. Other uses, such as for fillers in plastics, for agricultural mulching, and for composting (see Composts, in this section) also might require large quantities. This entire subject should receive very serious study so that any advantage of agricultural waste materials for these uses might be discovered and ways of overcoming the disadvantages be developed. Specific suggested studies are:

1. A study of the possible use of agricultural wastes as fillers for plastics and rubber. Materials used for this purpose must meet a number of requirements relating to molding and curing qualities and properties of the finished articles including density, strength, finish, and resistance to water and chemicals. Agricultural waste materials are abundant and usually available at sufficiently low cost to attract attention for such uses, but they have not been used extensively because of deficiency in one or more of the requirements. Research work should be undertaken with the object of overcoming these deficiencies.

2. Studies on briquetting the various agricultural wastes, either by themselves or in combination with other materials, such as low-grade coals, lignite, and tars from destructive distillation operations, to form low-cost and easily transported fuels.

3. An investigation on the possibility of pressing agricultural wastes into formed masses less dense than briquettes, which can be made on the farm for use there, or used locally for fuel or for other purposes.

4. Study on the use of agricultural wastes as poultry litter and animal bedding. These materials are now used for these purposes on almost all farms, and improvements in these practices should be possible through research. Appreciable expansion in the amounts of agricultural wastes used for such purposes, however, appears to be less likely than in some other lines.

5. Study of the use of agricultural wastes as diluents and spreading agents for insecticides and other poisons used in agricultural work. Finely divided agricultural wastes have found acceptance for this purpose, and their use might be increased through additional research.

6. Additional research on the use of agricultural wastes for mulching purposes. (See section on Composting.)

7. Studies on the use of agricultural wastes (1) as pack materials; (2) as cleaning, scouring, and polishing compounds; (3) as absorbents for solvents used in cleaning furs; (4) as mechanical carriers for mold or bacterial growths in fermentation processes; and (5) as filtering materials.

8. Study of possible biological utilization by animals, insects, or other forms of life to yield more useful products.

9. Investigations on the use of agricultural wastes as adhesives or binding materials which might be used in connection with felting or other procedures to provide cheap membranes for insulation, road covering, canal lining, etc.

COTTON AND OTHER FIBER CROPS

The term "fiber crops" as used in this report does not cover the entire field of fibers of vegetable origin, but is confined to such fibrous materials as cotton, flax, hemp, ramie, broomcorn, jute, Manila hemp, henequin, and sisal. Wood fiber is separately treated in the section on Forest Products, and such other sources of fiber as the cereal straws, cornstalks, and bagasse are included in the section on Agricultural Wastes. In spite of this division, the chemist recognizes a fundamental similarity among all of these materials; they are, in short, the cellulosic fibers, and many of their important properties are the properties of cellulose, even though cellulose may be a minor constituent. In view of this important likeness, and the influence which it has had on the planning of research projects, the next section concerns fundamental research on cellulose itself.

The fiber crops of the United States, as listed above, fall into two general classes—textiles and nontextiles. Only one crop in each group—cotton in the former and broomcorn in the latter—is of significant and widespread importance from a commercial standpoint. In 1937 the cash farm income from cotton and cottonseed was 864

million dollars, while the farm value of broomcorn was about 3.5 million dollars. Other textile fiber crops—among them fiber flax, hemp, and ramie—are being grown only experimentally or in quantities of only a few hundred tons. However, these less important fiber crops are of interest because they represent potential substitutes for the same or similar fibers now imported into the United States.

In 1937 approximately 6.04 billion pounds of textile fibers were consumed in the United States. Of this total, 3,630 million pounds (60 percent) was cotton; 1,045 million pounds (17 percent) was jute; 560 million pounds (9 percent) Manila hemp, henequin, sisal, and other hard fibers; 354 million pounds (6 percent) wool and mohair; 302 million pounds (5 percent) rayon; 64 million pounds (1 percent) silk; and about 51 million pounds (between 1 and 2 percent) was flax, hemp, and ramie.

All of the silk, jute, Manila hemp, henequin, sisal, and other hard fibers and practically all of the flax, hemp, and ramie were imported. In addition, about half of the wool (largely a carpet wool of lower average quality than our domestically produced wool), about 3 percent of the cotton, and small quantities of the rayon were imported.

Of the fibers imported into the United States in 1937, raw silk had the highest valuation, approximately 110 million dollars. In addition, about 10 million dollars' worth of silk in various stages of manufacture was also imported. Raw wool imports had a value of about 95 million dollars and wool manufactures and semimanufactures a value of approximately 30 million dollars. Most jute imported into the United States is in the form of burlaps and bags. Raw jute and jute butts imported in 1937 were valued at about 10 million dollars, while jute, burlaps, bags, etc., were valued at about 50 million dollars. Flax, hemp, and ramie fibers, mostly in manufactured form, had a declared value of 35 million dollars, the principal fiber in this group being flax. Manila hemp, sisal, henequin, and other hard fibers (mostly manufactured) were valued at nearly 35 million dollars. Unmanufactured cotton imports had a value of 17 million dollars, while cotton manufactures and semimanufactures had a declared value of about 55 million dollars. Imports of rayon yarn, rayon staple fiber, rayon waste, and rayon manufactures were valued at 9 million dollars.

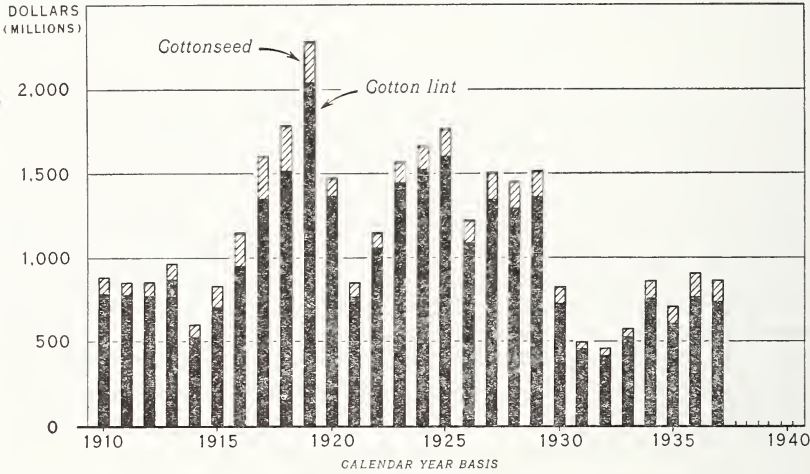
In the past more than half of our domestic crop of cotton has been exported, but within recent years our exports have fallen off sharply, amounting in 1937 to less than a third of the crop for that year. The falling off of our exports within recent years has been the major factor in the declining total demand for American cotton, since domestic consumption has been fairly well maintained. From 1920 through 1929, cash farm income from the sale of cotton and cottonseed averaged 1.4 billion dollars per year, but for the 8 years, 1930 through 1937, cash farm income has averaged 0.7 billion dollars per year (table 4 and the following chart).

TABLE 4.—United States cash income from cotton lint and cottonseed, 1910–37

Year	Cash income from cotton lint and cottonseed	Averages
	1,000 dollars	1,000 dollars
1910.....	880,458	1,180,556
1911.....	854,675	
1912.....	851,685	
1913.....	968,196	
1914.....	602,043	
1915.....	829,973	
1916.....	1,148,310	
1917.....	1,603,731	
1918.....	1,784,528	
1919.....	2,281,958	
1920.....	1,475,758	1,415,749
1921.....	852,247	
1922.....	1,147,874	
1923.....	1,568,802	
1924.....	1,663,484	
1925.....	1,762,361	
1926.....	1,222,342	
1927.....	1,500,031	
1928.....	1,452,644	
1929.....	1,511,950	
1930.....	824,145	712,854
1931.....	496,956	
1932.....	460,694	
1933.....	577,551	
1934.....	862,854	
1935.....	711,786	
1936.....	904,879	
1937 ¹	863,970	

¹ Figures for cotton lint are preliminary.

FARM INCOME FROM COTTON, UNITED STATES, 1910-37



U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

Cotton is our most important fiber crop, not only from the standpoint of total value and total quantity produced, but also from the standpoint of its widespread production (see map, p. 82). In practically every Southern State, cotton is of foremost importance to the economic well-being of the citizen. The production of broomcorn,

the second most important fiber crop of the United States, is more localized with the center of production in the Oklahoma panhandle. Hemp, once an important domestic crop, is now produced only in small quantities, most of the crop being raised in Wisconsin. Fiber-flax production is confined to the Willamette Valley of Oregon and to small areas of Michigan. Ramie is grown only experimentally in this country.

COTTON

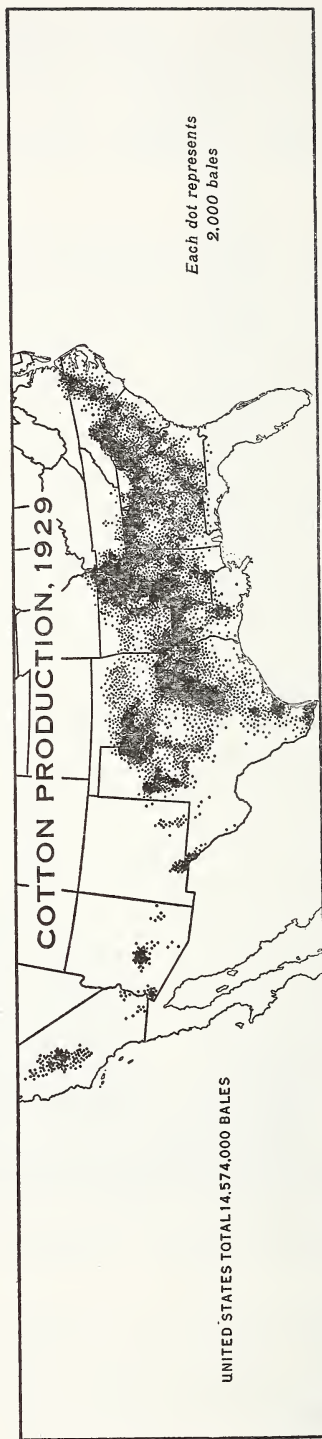
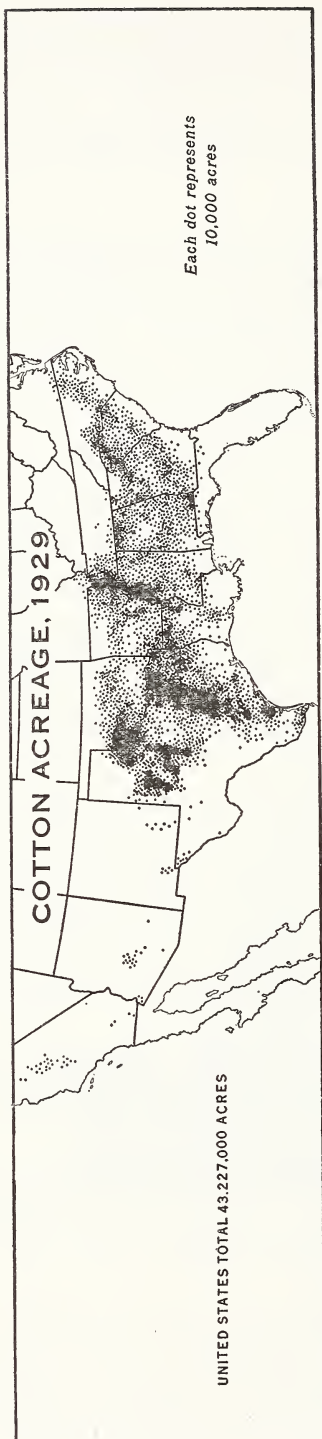
Cotton is the great cash crop of the United States. It has also been for many years our most important export crop. The region of production—the Cotton Belt—extends broadly from the Carolinas westward through the greater part of Texas and Oklahoma. Considerable quantities of cotton are grown under irrigation in California, New Mexico, and Arizona, but normally such quantities are small in proportion to that grown in the main part of the Cotton Belt. These regions are shown graphically on the accompanying maps.

There have been many years in which domestic growers have received more than 1,500 million dollars cash for 1 year's cotton crop, including the returns from both lint and seed. During the depth of the recent depression, however, this income dropped below 500 million dollars. From 1920 to 1929 the average was about 1,400 million dollars, but since 1929 the cash income from cotton and cottonseed (exclusive of Government payments) has averaged just over 700 million dollars and has not risen again to the billion-dollar mark. During the last 10 years, the cash farm income from cotton and cottonseed in the 10 principal cotton-growing States accounted for about 50 percent of the total cash income to farmers of those States from all crops and livestock combined. In Mississippi the cash return from cotton was as high as 75 percent of the total.

Cotton production in the United States has fluctuated considerably from year to year, but until about the time of the World War the trend was always sharply upward. The ravages of the boll weevil, which became very severe at that time, curtailed production sharply for several years, but the subsequent recovery carried average production during the 5 years ended with 1929 to a level higher than during any previous 5-year period. Since 1933 acreage and production have been influenced by the reduction programs of the Agricultural Adjustment Administration.

Over the last 25 years this country has been accustomed to harvest 27 to 45 million acres of cotton. The crop during this period has ranged from about 8 million to nearly 19 million bales, the latter in 1937. The production of cottonseed has been between 3.5 million and 8.5 million tons.

Texas is the leading producing State, with an average annual output for the 10-year period 1927-36 of about 4 million bales. The other leading States are Mississippi, Arkansas, Alabama, Georgia, Oklahoma, South Carolina, Louisiana, and North Carolina.



The cotton-growing industry had its beginning in what is now the eastern part of the Cotton Belt, but the expansion westward was rapid, and by 1900 Texas alone was producing about one-third of the total. On a percentage basis this general westward trend continued until 1933, when the five States, Texas, Oklahoma, New Mexico, Arizona, and California, produced 46 percent of the total. Since 1933, however, the average annual share of the western area has been only about 35 percent.

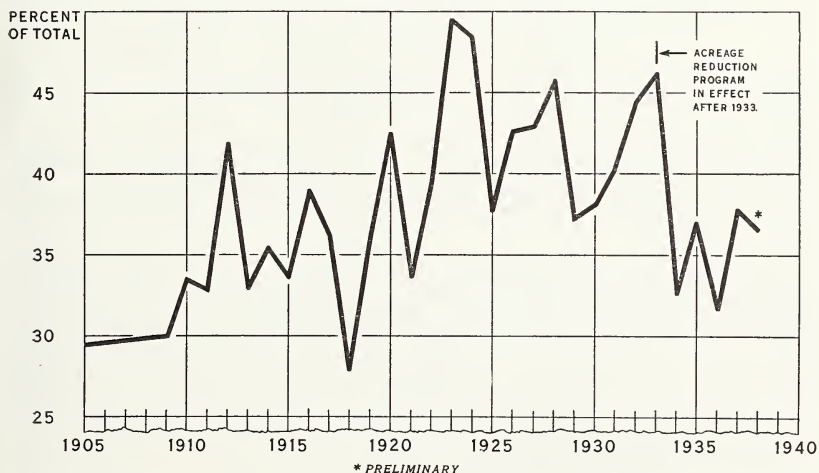
Shifts in acreage from east to west were caused primarily by boll-weevil infestations, which were much more disastrous in the eastern and central parts of the Cotton Belt than in the western, and by differences in relative advantages in cotton production. But there were also other factors, such as the relative prices of cotton and alternative crops in the older areas and the desire for land ownership and the opportunities presented in the newer areas. The net increases and decreases in cotton acreages that took place between 1909 and 1929, and the percentage of the annual crop grown in the western area from 1900 to 1938 are shown on the accompanying maps and chart.

In the United States cotton is planted in the spring and harvested in the fall. Most of the crop is ginned and sold during October, November, and December. In most cases farmers have their cotton ginned and then sell the lint and seed separately, though a few sell their cotton "in the seed," that is, unginned. In the past 10 years lint cotton has accounted for approximately 88 percent of the cash income received by farmers for their cotton crops.

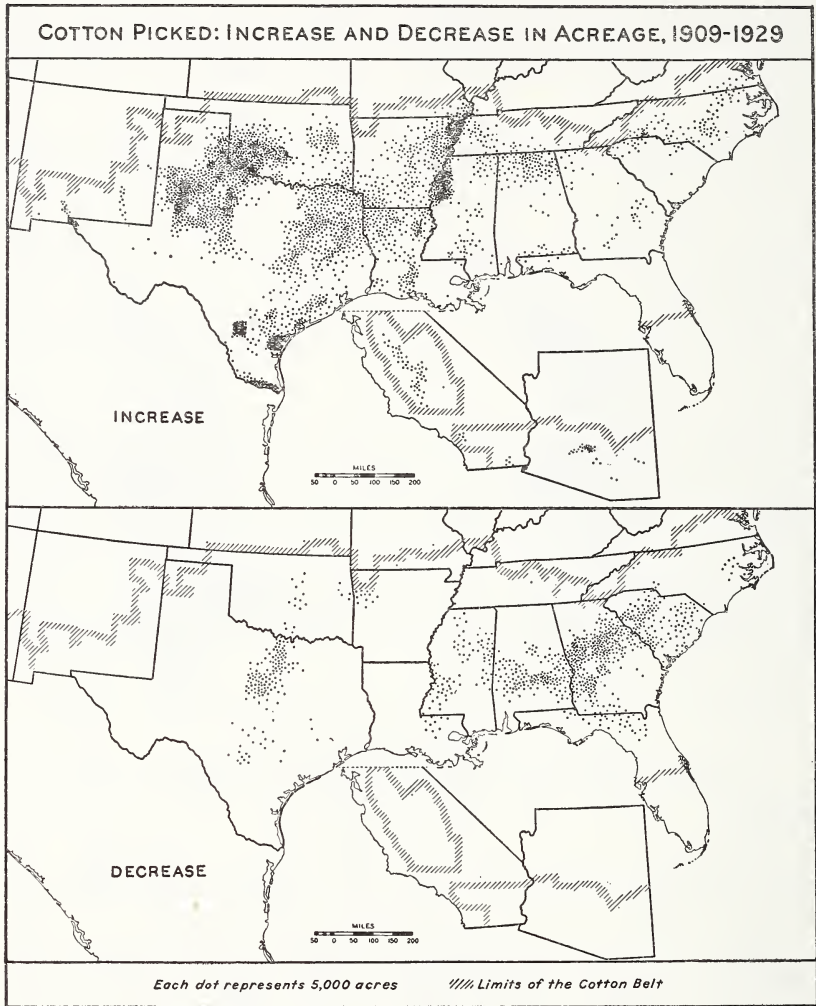
From the gin the greater part of the lint cotton goes into the warehouses of merchants and cotton mills. From these it is withdrawn as needed for domestic consumption or export. Usually some cotton

INCREASING IMPORTANCE OF COTTON PRODUCTION IN THE WESTERN AREA

FROM 1905 TO 1933 COTTON PRODUCTION IN TEXAS, OKLAHOMA, ARIZONA, CALIFORNIA, AND NEW MEXICO INCREASED FROM ABOUT 30% TO ABOUT 45% OF TOTAL UNITED STATES PRODUCTION. SINCE 1933 PRODUCTION HAS BEEN INFLUENCED BY ACREAGE REDUCTION PROGRAMS.



is held by growers in the hope of obtaining better prices at a later date, and within recent years the Government has taken several million bales in storage on loans.



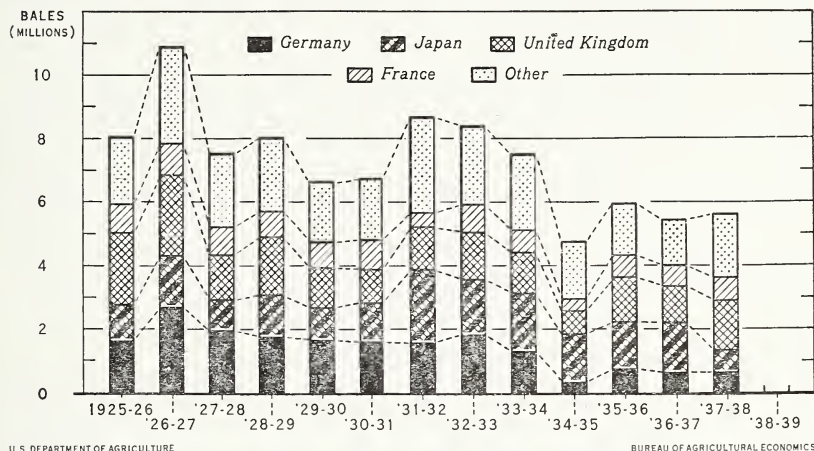
U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

Normally, more than half of the lint cotton produced in the United States is exported to foreign countries. An idea of the size and trend of this export trade may be given briefly. In the season beginning August 1900, we exported 6.6 million running bales (equal to 65 percent of the crop); in 1910, 7.8 million (67 percent); in 1920, 5.7 million (43 percent); in 1926, a record high of 10.9 million (62 percent); in 1930, 6.8 million (49 percent); in 1935, 6 million (57 percent); and in 1937, 5.6 million bales (31 percent).

Until recently, more cotton was exported to England than to any other country, but with the rise of the textile industry in the Far East Japan began taking increasing quantities—more than England in the 1930-31 marketing season. Japan's war with China and her recent restrictions on imports of cotton have lessened her importance as a consumer of our cotton in the last 2 years. The exports of cotton from the United States are indicated on the accompanying chart.

UNITED STATES COTTON EXPORTS BY COUNTRIES



During recent years the annual consumption of cotton in the United States has varied from a little less than 5 million to almost 8 million bales. More than three-fourths of this cotton was manufactured by mills located in the cotton-growing States, with most of the remainder manufactured by mills in the New England States. A few generations ago, however, the situation was just the reverse. In 1850, for example, mills in the cotton-producing States consumed less than 15 percent of the total mill consumption for that year. By 1900 this proportion had risen to nearly 40 percent.

When the cotton-textile industry was first established in the United States, about 1800, cotton fabrics were used mainly for clothing and household furnishings. During recent years, an average of only about 60 percent of the cotton fabrics produced are going into clothing and household furnishings, while what are called "industrial" uses account for the remaining 40 percent. It is significant that the quantity of cotton consumed for manufacture into all types of fabrics is very closely associated with general industrial activity throughout the country. When the country as a whole is busy and prosperous, cotton is consumed in large quantities for clothing, household furnishings, and industrial purposes, but when industrial activity is restricted and consumer income is low, the consumption of cotton is adversely affected.

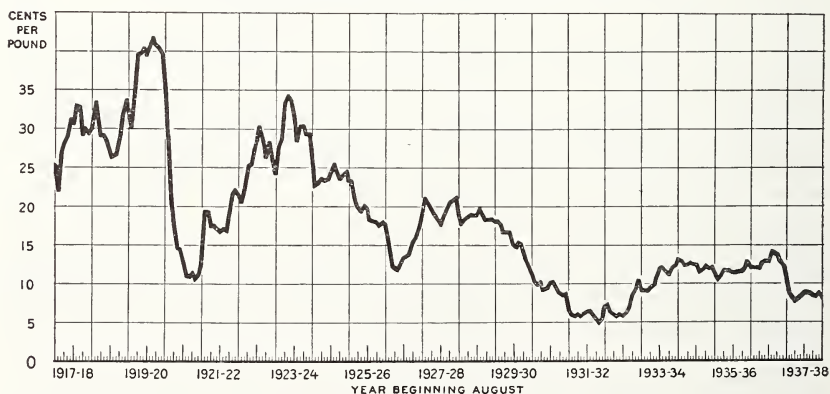
While cottonseed, except for planting purposes, was a total waste only a few generations ago, it has in recent years provided cotton farmers with an annual cash return of 40 million to more than 160 million dollars. Cottonseed now ranks about tenth or eleventh in farm income among all farm crops in the United States.

When the seeds go to oil mills, they are run through machinery that removes the linters or shorter fibers which adhere to the seed after ginning. The seeds are then crushed to yield oil, cake and meal, and hulls. Linters are used principally as a padding material for bedding, mattresses, furniture, and automobile seats. In recent years large quantities of the lower grades of linters have been used as a source of cellulose compounds. The oil, which is by far the most important cottonseed product, goes principally into vegetable shortenings, margarine, soaps, and paints, and into the manufacture of artificial leather. Cake and meal are used mostly for stock feed. The hulls also are used in stock feed, and to some extent as a packing and stuffing material.

The case of lint cotton doubtless presents the most acute large-scale surplus problem in the country. The restriction of production in the United States during the last few years, together with a marked recovery in world economic conditions, reduced the world carry-over of American cotton from 13.3 million bales in 1932 to 6.2 million bales in 1937. But the record crop of 1937-38 and a marked recession in business conditions resulted in a new record high carry-over of 13.7 million bales of American cotton on August 1, 1938. This carry-over, even with the comparatively small 1938 crop, gives a supply of American cotton for the current season of between two and two-and-a-half times as large as the season's probable consumption.

Despite the fact that more than 10 million bales of the 1938-39 world supply of United States cotton is being withheld from regular marketing channels by the Federal Government, cotton is selling for exceptionally low prices. In fact, the average price of Middling $\frac{7}{8}$ -inch cotton in domestic markets during the first 4 months of the present marketing season was nearly three-fifths below the average for the decade of the 1920's, and with the exception of 1931 and 1932 was the lowest for any corresponding period since the outbreak of the World War. The following chart shows the trend of prices from August 1917 to August 1938.

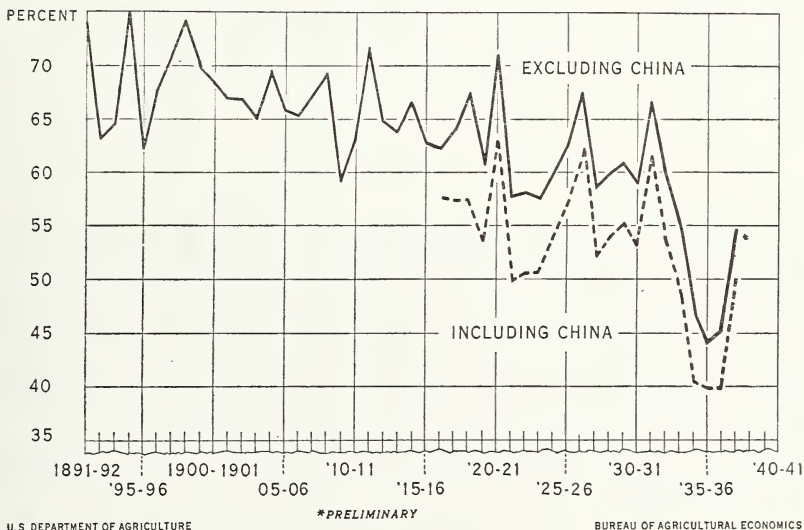
MONTHLY AVERAGE PRICE OF MIDDLING $\frac{7}{8}$ -INCH SPOT COTTON
FOR TEN DESIGNATED MARKETS, AUG. 1917 TO DATE



Many factors have contributed to the present extremely unfavorable cotton situation. To a large extent, however, it has grown out of the reduced foreign demand for United States cotton resulting from such factors as increased production of foreign cotton, increased international trade restrictions, and enforced as well as voluntary substitution of rayon for cotton in many foreign countries. The increased competition from rayon in the domestic market has also been of considerable importance.

During each of the last 3 years, the production of commercial cotton in foreign countries has been 16 to 19 million bales, compared with an average of a little less than 9.5 million bales in the decade of the 1920's. The accompanying graph shows the relation of United States production to total world production since 1891. The world production of rayon has shown a very marked upward trend since before the World War, but during the 1920's the average annual production amounted to only 400,000 equivalent bales of 478 pounds. In 1937 the equivalent of about 4 million bales was produced.

COTTON: UNITED STATES PRODUCTION AS A
PERCENTAGE OF WORLD PRODUCTION, 1891 TO DATE



The cottonseed situation is not nearly so unfavorable as is the situation with respect to lint cotton, although cottonseed prices during recent months have averaged about one-third less than in 1920-29. However, even though both prices of, and income from, cotton and cottonseed were equal to those of the 1920's, there would still be great need for undertaking additional research designed to increase the income and welfare of southern farmers. Even in the 5 years 1924-28, the annual cash farm income from all farm products sold plus the value of farm commodities consumed in farm households in the 10 major cotton-producing States averaged only \$184 per capita of farm population. This was less than half as large as for the remainder of the United States. During this 5-year period the farm income from

cotton and cottonseed accounted for 57 percent of the average cash income per person on farms in the 10 major cotton-producing States.

Since 1929 cottonseed has accounted for one-seventh to one-twelfth of the total farm value of the crop. For a more complete statement of the economic situation of cottonseed, as well as for the present and suggested research on the seed, oil, and cake, see the section on Oil Seeds and Crops.

COTTON FIBER

Fiber obtained from the cotton plant is of two distinct types, (1) cotton lint, composed of the longer fibers separated from the seed at the gin, and (2) cotton linters composed of the shorter fibers remaining on the seed after ginning and later removed with varying degrees of completeness by special machinery at the cottonseed oil mills. More than 98 percent of the lint cotton is spun into yarns, whereas only a very small proportion of the linters is spun. In this country, more than half the linters is used in batting, wadding, mattress felts, and other padding materials, but most of the exported linters, which has been around 15 to 20 percent of the total domestic supply during recent years, is reported to go into chemical uses. The proportion of linters to lint, by weight, seldom exceeds 1 to 10.

PRESENT RESEARCH

Cotton Lint

The following lines of work are under way:

Production research.

1. Breeding and genetic researches to develop varieties and strains high in yielding capacity, of fiber length and quality satisfactory for specified uses, resistant to diseases, insects, and other factors adversely influencing yield and quality, and best adapted to the various sections of the cotton-producing area. Specific objectives include greater uniformity of fiber properties, production of cotton with seed of a higher oil content, improved adaptability for mechanical harvesting, and suitability for specific uses such as automobile tires.

2. A number of studies in morphology and developmental anatomy, such as an investigation of the causes of immature fiber and other fiber imperfections.

3. Studies of the most important pests and diseases, including the boll weevil, bollworm, root rot, and cotton wilt.

4. The relationship of yield to quality (length, fineness, strength, etc.) and the influence of soil, irrigation, fertilization, type of culture, climate, and other environmental factors upon both yield and quality. Other points being studied are the dependence of fiber qualities on the density of growth of the fiber on the seed, and the influence of soil and stage of growth on the chemical composition of the plant. Hydroponics is receiving some attention.

5. Studies of methods designed to lower the cost of production.

6. Engineering studies on the development of cotton production machinery, especially of a satisfactory harvesting machine.

Ginning methods and equipment.

7. Intensive and extensive research on ginning machinery and methods of operation with the purpose of obtaining more efficient and economic handling and ginning of seed cotton, of minimizing damage to the lint, and of securing a superior preparation: These investigations include research on both saw and roller gins and on improvements in cleaning, extracting, and drying equipment.

Research on fiber properties.

8. Intensive research on the physical properties of cotton fibers and the relation of these properties to cotton utility: Among the properties receiving attention are color, length, fineness, maturity, strength, adsorptivity, and elasticity. Special studies are being made of the relations between the fiber properties and their cell-wall and cross-sectional structure. Much of this research is being carried on with a view to setting up new and improved quality standards for raw cotton. Further reference to work of this nature will be found in the paragraph on "Testing and standardization" and in the section on "Fundamental cellulose."

Processing machinery and methods of manufacture.

9. Limited studies designed to develop entirely new machinery and methods for processing cotton into yarns and fabrics: Most of the research in this field is confined to improvements in existing machinery and in the technique of manufacture. All such work is aimed toward lowering the cost of manufacture or improving the quality of the product, or both.

Yarn and fabric development.

Work in developing new and improved yarns and fabrics: The results of research along this line is typified by the new clothing and household fabrics that are brought on the market each year, by new types of fabric for automobile tires, and by various innovations in bags for packaging merchandise. Specific examples are men's cotton slacks for summer wear, open-mesh bags for packaging fruits and vegetables, cotton bagging for covering cotton bales, cotton fabrics for reenforcing bituminous-surfaced roads, and cotton mats for curing concrete. Research on many such fabrics does not end with the development of the fabric, but often continues with the purpose of further improving the utility of the fabric or else in reducing the cost of manufacture. The results of commercial tests indicate the desirability for further work.

Research now in progress on the development of new and improved cotton yarns and fabrics is conveniently classified under the following headings:

10. Industrial fabrics: Approximately 40 percent of all the cotton consumed in the United States each year goes into industrial fabrics. Specific objects of research in this field include a cotton twine suitable for tying letters and parcels in connection with the handling of mail; a more durable cotton tire fabric, especially for use in high-speed, heavy-duty truck and bus service; various types of cotton bagging for covering cotton bales, cotton bags for packaging certain agricultural commodities not now handled in cotton bags; cotton fabrics for reenforcing bituminous-surfaced roads, cotton mats for curing concrete,

and fabrics for use in preventing erosion on seeded slopes; cotton shroud cords for parachutes, to replace those now made with silk.

11. Clothing and household fabrics: Approximately 60 percent of the cotton consumed in the United States goes into clothing and household fabrics, with clothing alone accounting for about 40 percent, or about the same as industrial uses. Research in this field is concerned mostly with the development of special yarns and weaves, either of cotton alone or of cotton mixed with other fibers. New types of cotton hosiery, underwear, curtains, and summer clothing are typical examples of objects of research in this field.

Finishes and treatments.

Finishes and treatments for cotton textiles may be divided into two main classes—those which are applied during intermediate stages of the manufacturing process to facilitate processing or handling, and those which are applied to finished yarns and fabrics for the purpose of altering their natural properties for specific uses. Research in progress on treatments of the first type is concerned mainly with various types of starches used for sizing yarns preparatory to weaving, but there is also some work being done with other sizing material. Gelatine and other proteins are among those now being studied.

Research on finishes of the second type is quite varied. Most of the new and improved finishes on which work is being done may be classified as follows:

12. Mercerization; specifically the use of cuprammonium or other alkaline solutions in the place of sodium hydroxide, the reaction to mercerization of fabrics consisting of mixed fibers, and change in composition of the fiber during mercerization.

13. Permanent shrinking of cotton fabrics, either by chemical or mechanical treatment, or some combination of the two, with the particular aim of finding less expensive methods than those now used.

14. New and more efficient methods of waterproofing, among the particular materials under investigation for this purpose being grease, oil, wax, heavy metal soaps, tar, asphalt, rubber, varnish, paint, lacquer, and resins.

15. Finishes of special applicability to clothing and household fabrics, such as those designed to improve the hand and draping properties, to increase resistance to creasing and soiling, to improve the luster, and to provide fabrics with greater stiffness for certain uses: Problems associated with the printing and dyeing of cotton fabrics, of paramount importance in this field, are receiving a great deal of attention. At present, most of the research along these lines makes use of such substances as urea-formaldehyde, vinyl and acrylate resins, protein and starch sizes, cellulose ethers and esters, cellulose dispersions, and strong acids (which produce hydrocellulose).

16. Miscellaneous finishes and treatments: In addition to work referred to above, research is also being done on finishes to increase the resistance of cotton fabrics to the action of fire, acids, micro-organisms, and light, and to improve the adsorptive properties for certain uses.

Testing and standardization.

17. Research on the development of testing methods, standards and specifications for fiber, yarns, and fabrics: In particular, the correlation of physical and chemical tests on cotton with the spinning

value, the quality of yarn and fabric, and the performance of the fabric is being studied. Rapid methods are being sought for the determination and measurement of the qualities of raw cotton. Particular tests being studied are determination of moisture adsorption, tensile strength, percent elongation, pliability, fineness, length, maturity, variation of these properties, fluidity in cuprammonium solution, luster, dielectric constant and other electrical properties, resistance to dyeing, bleaching, preoxidation, alkali solubility, copper number, and accelerated aging. The reliability and speed of spinning tests are being increased. The use of X-rays as a method of measuring the strength of raw cotton is being investigated. The identification of fibers in fabrics is also a subject of much interest. Specific work in this line includes the use of fluorescence as an aid and the development of a satisfactory microtome.

Economic research.

18. Studies of the general factors of demand affecting the total and per capita consumption of American cotton and of competing growths and other fibers: Attention is being given to factors operating in foreign markets as well as to those which apply especially in domestic markets. Studies more basic than these to an understanding of the utilization of cotton are those which follow the consumption of cotton for specific uses, determining both the quantity and quality of cotton going into them as well as the set of demand factors peculiar to each use. What is usually referred to as "market analysis" is included in this type of work. Lastly, there are economic studies which view the entire cotton industry as an entity and seek to evaluate the relative efficiency with which various types of economic organization within the industry operate. Economics embraces such a broad field that the large amount of research being conducted has been outlined in only the most general terms.

Miscellaneous research.

In addition to the aforementioned research, considerable work is being done that does not fall strictly within any one of the foregoing classifications. This may be classified as follows:

19. Development of a satisfactory device for the permanent identification of individual bales of raw cotton, to be applied at the gin, to facilitate the handling and marketing of cotton.

20. Studies of a method to take a representative sample of lint automatically during the ginning process.

21. Investigations to find a use for the wax on cotton fiber: Byproducts from the ginning process are being considered elsewhere in this report, particularly in the section on oilseeds.

22. Investigation of many types of laminated products, including bonded metal where cotton or other fabric is faced on metal backgrounds by pressing it into a surface film of melted tin; decorative panels consisting of cotton fabric glued onto wood veneer; and laminated products of unspun cotton and light-weight fabric using cheap adhesives.

23. Research directed toward more efficient and less damaging methods in the cleaning and laundering of fabrics: The increased use of deodorants and depilatories is responsible for research aimed at the prevention of damage to clothing from this cause.

24. Cotton rags are used to a large extent in the manufacture of paper, fiberboard, and roofing felt. The presence of rubber in some of the newer composite fabrics has prompted the study of its removal prior to such reuse. An outlet being developed for dyed rags consists of pulverizing them for use in decorative finishes.

25. Compilation of a bibliography of hundreds of different present and potential uses of cotton and cotton linters.

COTTON LINTERS

While the principal use of cotton linters is for padding and stuffing, practically all of the research is devoted to the preparation and utilization of its chemical derivatives. For this purpose the linters is specially cleaned and purified to form what is known as chemical cotton, which is one type of industrial cellulose. Pulpwood is the only other major source of industrial cellulose, and for some purposes wood cellulose derivatives are replacing chemical cotton.

Owing to the extreme importance of rayon as a competitor of cotton and the fact that it represents the largest single outlet for chemical cotton, it will be given a detailed treatment similar to that for lint cotton.

Of the three commercial types of rayon produced in this country, acetate and cuprammonium are manufactured from cotton linters, while viscose is now prepared almost entirely from wood pulp.

Although not specifically mentioned, much of the research in progress on viscose rayon is also covered in this section, as the research on this material is, in many cases, identical with that on the other types of rayon. Furthermore, except for some special cases, it will not be necessary to discuss separately the research on transparent sheeting and film, as, up to a certain point, this research is practically the same as that devoted to the manufacture of rayon itself. In the following discussion, the term "rayon" includes both filament rayon and rayon staple fiber, unless otherwise stated.

Comparatively little research is being conducted on raw linters and chemical cotton, but studies on rayon and other derivatives of chemical cotton are extremely numerous and varied. Specific projects are:

Raw linters.

1. Studies in processes of delinting seed and the cleaning of unpurified linters.
2. Studies in flame-proofing linters for use in insulation of houses.
3. Efforts to increase the utilization of the material in paper stock.

Preparation of chemical cotton.

4. Research on the details of bleaching and digestion and the relation of these processes to the properties of the finished derivatives.

Utilization of chemical cotton and its derivatives.

5. Research on rayon, including:

(1) Solutions for spinning: Most of this research is directed toward:
(a) The introduction of wood pulp as a raw material for acetate and cuprammonium rayon. (b) Experiments, now entering the commercial stage, to produce a purified kraft pulp suitable for rayon. (c) Some work on entirely new rayon processes, but this is much less advanced. It includes the spinning of cellulose dispersed in quaternary ammonium hydroxide solutions and the production of rayon from

the cellulose ethers. Both these processes have been studied in textile finishes also. (d) Research on improving the acetylation process.

(2) Research to improve machinery and processes used in the manufacture of rayon and rayon textiles. This includes (a) specific studies on the effect of the type of pulp, purity of water, and tension during spinning upon the properties of the yarn and fabric; (b) work on starch size; (c) research on delustering.

(3) Studies of special treatments and finishes for rayon, including: (a) Studies to increase the elasticity of rayon by the addition of latex or chlorinated rubber to the spinning solution or by coating fabric with rubber or with a mixture of rubber and viscose, using latex-casein or alkaline protein glues; (b) treatment with formaldehyde to prevent crushing, synthetic resin finishes to reduce creasing, and non-slip finishes to prevent pulling at the seams; (c) special treatments for rayon crepe and rayon brocade materials.

(4) Research on rayon staple fiber (continuous filament rayon cut into definite lengths which can be processed satisfactorily on most types of textile machinery). This includes: (a) Investigations with the aim of modifying processes and equipment to obtain optimum results; (b) delustering, bleaching, dyeing, special finishes, and effects (such as a permanent crimp), with a view to improving the general utility of staple fiber in textiles.

(5) The processing of yarns and fabrics made from mixed fibers (various combinations of rayon, silk, cotton, wool, casein fiber, linen, etc.). Fabrics made of mixed fibers present special problems. For instance, the use of mixed fibers has awakened interest in the moth-proofing of rayon. Although rayon is indigestible to the larvae, it is frequently damaged in mixed fabrics.

(6) Investigation of the mercerization of filament rayon, of staple fiber, and of mixed fabrics containing these fibers.

(7) Research on the improvement of rayon tire cord: One of the most important new uses for rayon is in tire fabric, where it is claimed to possess superior heat-resisting properties over ordinary types of cotton-cord fabric for use in heavy-duty, high-speed truck and bus service.

(8) Considerable work on other new uses for rayon: (a) In two special types of yarn, it is used in combination with rubber, the lastex type, which consists of a rubber core wound with rayon, and the statex type, in which cellulose acetate is dissolved from the rubber-coated acetate filament to leave the tubular rubber filament; (b) special iridescent effects have been produced from viscose cellulose in the manner described under the heading of "Alkali-Soluble Cellulose Ethers"; (c) study of the use of rayon or scrap rayon in paper, carpets, and as a reinforcement for synthetic resins; (d) the regeneration of cellulose in the form of a sponge.

(9) Research on testing and specifications, following closely that discussed under the same heading in connection with cotton fiber.

6. Research on cellulose nitrate: (1) Modifications of the nitration process, as well as the formulation of nitrate lacquers and films, especially with respect to plasticizers and solvents. Each new use is likely to require a new formulation. (2) Research on emulsion lacquers and lacquer adhesives. Certain industries, such as the nitrocellulose and the leather and shoe manufacturers, have already done considerable work recently along this line. (3) Work on the use

of this and other esters in finishes. (4) In the case of photographic films, considerable research on the storage and care of permanent records and the preservation of archive material of all sorts.

7. Research on cellulose acetate: Research on acetate rayon is extensive, following the lines noted under rayon. The noninflammability of cellulose acetate makes it desirable as a substitute for cellulose nitrate in almost every use of the latter except as an explosive. Accordingly we find research on the acetate paralleling that on the nitrate and dealing with the acetylation process and on the formulation of lacquers, plastics, and films: (1) Formulation of safety glass sandwiches; (2) research on improving cellulose acetate as a wrapping film and as an insulating sheet; (3) improvement by formulation and by mechanical treatment, the resistance to heat and moisture, the clearness, the flexibility, and the strength of acetate plastics; (4) a specific attempt to produce an acetate which will better stand the high temperature necessary for injection molding; (5) research on the triacetate, which has quite different properties from the ordinary (secondary) cellulose acetate; (6) studies of the possibility of using cellulose acetate, which transmits a relatively high percentage of ultraviolet light, as a substitute for glass, especially for hothouses and cold frames; (7) minor research relating to use of cellulose acetate in finishing textiles, leather, etc.

8. Research on other esters: (1) Preparation of many simple cellulose esters on a laboratory scale and testing in films, lacquers, etc., especially the propionate, butyrate, and stearate; (2) studies of mixed esters, the nitroacetate, acetopropionate, and acetobutyrate being of most recent interest.

9. Research on other derivatives: (1) The water-soluble ethers include some types of methyl, ethyl, and hydroxyethyl cellulose. Research has been conducted on these materials with the aim of using them (a) in sizing and finishing textiles, (b) in sizing cellulose for paper or imparting wet strength to the paper, and (c) in various ways as a protective colloid, as for instance in thickening printing pastes or in delustering solutions. (2) The alkali-soluble ethers include other modifications of ethyl and hydroxyethyl cellulose which are insoluble in pure water. These solubilities have stimulated research on the use of this material in finishing and sizing solutions and in various coatings such as the glazed finish on playing cards. Iridescence has been produced on fabrics by drying in the presence of a foam formed by bubbling air through such alkaline solutions. (3) The water-insoluble ethers include methyl and ethyl cellulose of high substitution, higher alkyl ethers, benzylcellulose and most of the mixed ethers. Research on these compounds follows the same lines as that of cellulose acetate. They have the advantage of being much more stable compounds. A special case is that of certain partially etherified celluloses. For instance, p-nitrobenzylcellulose can be reduced and diazotized to give a dye base which is chemically part of the fiber. Waterproof fibers and fibers with special dyeing properties can be similarly produced, for instance by treating cellulose with a mixture of ketone and the hydrochloride of a tertiary amine or pyridinium compounds. (4) Ether-esters have also been prepared and investigated to some extent for commercial utilization. They are of two main types, the esters of low substituted ethers and the esters of hydroxyalkyl cellulose. Publications indicate that there is more

interest in this line of research in Europe than in the United States. Since the number of possible combinations and modifications is very large, an extensive patent literature on this subject is growing up.

WHOLE COTTON

Some work is being done on the growing, harvesting, and utilization of the entire cotton plant as a source of industrial cellulose, and special pulping processes are being worked out for this material.

SUGGESTED RESEARCH

The suggestions in this section are those submitted to the Survey representatives by the organizations and individuals interviewed and will be found to parallel closely research now in progress. In some cases, the suggestions cover completed research and present outlets for cotton. The reason for this, of course, is the feeling that improvements can be made at practically any point, so that a great many items in the section on present research will be duplicated in this list. The program of research to be found in part III of this report will contain only those projects which have been selected as most likely to bring about the results aimed at under the bill authorizing the new laboratories, and least likely to duplicate existing efforts. In both this section and part III, there will be obvious relationships with the chapter on cellulose.

COTTON LINT

Production research.

1. The most frequently suggested investigation consists of breeding, hybridization, and selection studies to develop certain desirable characteristics. Improvements in length and uniformity of staple, fiber strength, fineness, and other character properties, the development of a cotton with seed of maximum oil and protein content, of a cotton suitable for mechanical harvesting, of cotton with seed from which the lint may be more readily removed, of a short, woolly cotton to replace Chinese and Indian cotton in blankets and of improved cottons for certain other specific uses (for instance, in tire fabrics), have all been suggested.

2. Among the cotton pests the pink bollworm and the boll weevil have been mentioned for specific study. Stress has been laid on the study of harmful effects produced by bacteria and higher organisms upon cotton at any time from the beginning of growth up to and including its use in finished articles. It was suggested that such study include determination of the organism responsible (possibly associated with enzymes in some cases), of favorable and unfavorable environment, of tests for detection and amount of damage, and of preventive measures; a study of the effect of variety, weather, irrigation, fertilizer, etc., upon incidence and severity of attack and the proper methods of harvesting, ginning, and storage.

3. Other suggestions embrace the determination of the best variety for each locality, study of the relation of soil, culture, environment, and variety on the composition of the cotton (mineral content, etc.), and on the factors governing its general utility (quality of lint and linters, percentage of mill waste and properties of the manufactured products) and intensive study on how to lower the cost of production.

4. The relative merits and demerits of irrigated versus rainfall cotton were also recommended for study, following up preliminary studies and settling the question of whether irrigation produces an irregular cell structure.

Research on fiber properties.

5. The numerous suggestions of this nature can be condensed to a recommendation of further study on the fiber properties of different varieties and growths of cotton, to obtain a better knowledge of the relation between fiber properties and the properties of manufactured yarns, in order to be able to predict more closely the spinning value of any given lot of cotton, and in order to get a better estimate of possible uses and values. At present, it is necessary to spin a portion of each lot to determine its spinning value. It was pointed out that successful research along this line would make possible, among other things, the setting up of more precise and comprehensive standards for raw cotton and thereby lead to the more efficient utilization of the cotton crop, the quality of which varies considerably from year to year. (See also the paragraph on Testing and Standardization and the section on Cellulose.)

Ginning machinery and equipment.

6. Suggestions under this heading include specifically the further study of handling and drying of cotton before ginning, and of the methods and machinery used in cleaning, extracting, ginning, and compressing.

Processing machinery and methods of manufacture.

7. A fresh and broad approach to the whole problem of fabrication of cotton fibers, in order to obtain in yarns and fabrics more of the inherent strength of the component fibers than is now obtained with present methods of manufacture, was suggested as urgently needed, as well as critical studies of existing machinery and processes with a view to modifying them in such a way as to improve the quality or lower the cost of the product.

Yarn and fabric development.

A large proportion of the projects suggested by those interviewed referred to the extension of research along lines already in progress. The suggestions received fall into two general classes:

8. Industrial fabrics: (1) Development of cotton fabrics to replace those now made wholly or largely from jute and other imported fibers: specifically various types of bags, wrapping twine, rugs, rug backing, and bagging for cotton bales. (2) Development of more satisfactory cotton tire cord and tire fabric, and of a fabric suitable for use on wheel surfaces of farm machinery. (3) Further study of the use of cotton fabric in road construction and in cotton mats for curing concrete. (4) Study of the use of cotton for wrapping fruit and candy. (5) Development of a more closely meshed cloth for tent covers, temporary silo covers, and for use in fumigating corn cribs, trees, plants, etc. (6) Extension of the use of cotton in present outlets, such as bookbinding, filter press cloth, inking cloths, automobile seat covers, and roofing, by improving the quality of these fabrics.

9. Clothing and household fabrics: There were no very specific suggestions for research in this field, only general recommendations that new types of cotton products be developed to increase their utilization. A closer study of mixed fabrics and of fine fabrics and laces was suggested.

Finishes and treatments.

Suggestions for work on finishes and treatments may be grouped under the following heads:

10. Bleaching: Studies on the bleaching of off-color cotton and development of substances which would shorten the bleaching process.

11. Mercerization: Research to lower costs and improve properties of mercerized fabrics (specifically, a study of the Furness method of mercerization with copper oxide, ammonia, and soda).

12. Permanent shrinking: Continued study of methods of lowering the cost of permanent shrinking.

13. Waterproofing: Methods for rendering yarns and fabrics more resistant to water and to atmospheric moisture; waterproof finishes (soybean protein was mentioned) giving a gloss on ironing.

14. Finishes of special applicability to clothing and household fabrics, such as those designed to impart or enhance such desirable properties as resistance to crushing, soiling, abrasion and tearing, ease and fastness of dyeing, and luster; the development of treatments to give cotton certain desirable physical properties of other fibers. The specific types of coating listed under "Present Research" were all recommended for further study, as were substantive and tannin-mordanted finishes, immunized cotton, surface esterification and etherification, and surface treatment with dispersing agents for cellulose, such as the thiocyanate solutions. One general suggestion was that particular attention be given to the development of finishes which give the sought-for properties without destroying other inherent, desirable properties of the fabrics. Another was that present finishes be studied with a view to improving their permanency (in particular with regard to laundering and dry-cleaning).

15. Miscellaneous finishes and treatments: Finishes for increasing the adsorptivity, the tensile strength (some of the suggestions in the section on Cellulose bear on this point) and the resistance to micro-organisms and to fire (chlorinated wax treatments were advocated). Finishes aimed at specific fields of utilization were also mentioned, such as coverings for underground piping, artificial leather, insulation of various kinds, etc. Further research on starch and dextrin finishes was also suggested.

Testing and standardization.

16. Much work of a specialized and varied nature was suggested as necessary on the development of new methods for measuring cotton fiber, yarn, and fabric properties now measurable only with great difficulty or not at all; on the development of more rapid and practical test methods for properties now measurable in some form and degree; on the development of new apparatus and on the discovery and evaluation of other properties of cotton fibers and products to serve testing and standardization purposes.

17. Suggestions were made for further study on the method and meaning of viscosity determination and in general, for more uniform

methods and standards and for their evaluation. (See section on Cellulose.)

18. Particular suggestions deal with the development of a tensile strength test for tire cords which would simulate actual conditions of use and which would measure the breaking strength under a jerk rather than under a steady pull.

19. The quantitative determination of the various fibers in a given sample of cloth.

Economic research.

Many of the suggestions for economic research closely parallel, to some extent, work already in progress. Among the suggestions received for economic research are:

20. An intensification and broadening of present utilization studies to obtain more precise and comprehensive statistics on the quantities and qualities of cotton going into specific uses (such as sheets, towels, shirts, etc.).

21. Studies to determine the extent of various potential uses for cotton (such as in wrapping twine and various types of bags).

22. Analyses of the various factors influencing the consumption of cotton and of competing products.

23. Critical studies of processing and distribution costs for cotton textiles.

24. The collection and publication of statistics on the quality (with particular reference to "character") of current crops.

25. The collection of information on world cellulose resources especially with respect to location, quality, and quantities.

Miscellaneous research.

The following suggestions do not fall strictly within any one of the foregoing classifications:

26. Continuation of the search for more satisfactory means for the permanent identification of individual bales of raw cotton, and of a method for automatically taking a representative sample of lint during the ginning process.

27. New uses for off-grade cotton, mill waste, and raw cotton (other than by spinning into yarn).

28. Laminated and composite products for floor tile and general construction (cotton and cement) and the reinforcement of transparent cellulosic wrapping materials with cotton fabric: The direct addition of raw cotton to concrete mixes was mentioned as a possibility.

29. Improved method for utilizing rags in paper: Besides general suggestions on improvement of quality, especially in the bleaching or pretreatment processes, the use of cotton in cigarette paper, "Japanese" tissue and book paper was specifically recommended for study, as was a cheaper process for the manufacture of coarse rags.

30. Questions of such a nature that they should be coordinated with the problems in the section on Cellulose: These include the cause of heat instability and of relatively easy soiling (as compared to wool) and the factors governing the utility of a particular cotton for a particular purpose.

31. Investigation of the possibility of mechanically straightening and stretching the fiber to increase the surface luster of the fabric produced therefrom.

32. The maintenance of a continuous bibliographic and abstracting service.

COTTON LINTERS

Research on raw linters.

Many of the suggestions received for this type of research refer to an extension of present uses rather than to the development of new uses for linters. These suggestions include:

1. Its use in ropes, twines, stuffing, absorbent cotton insulation, felt, paper, and brake linings.
2. Its utilization as a filler for linoleum-type floor coverings and for high temperature and pressure fabrication with phenolic resins.

Research on the preparation of chemical cotton.

It has been claimed that one of the reasons why linters is being replaced by wood pulp as a raw material for industrial cellulose is that the properties of the linters are undesirably variable in a process which requires very close uniformity in the raw material. In order to determine the causes for these variations and to overcome them in commercial practice, the following suggestions have been made:

3. The effect of soil, variety, climate, storage, and processing on the quality of cotton linters intended for chemical conversion.
4. Improved culling, grading, cleaning, drying, and ginning of seed to produce linters more free from stalks and boll impurities.
5. The development of a more efficient delinting machine.
6. Improved methods of cleaning linters.
7. The development of dependable methods for blending large batches of linters and of tests which would quickly characterize a batch as to suitability.
8. More satisfactory methods for the recovery and processing of hull fiber (a very short linters removed from the crushed hulls) into chemical cotton and for the economic utilization of the residual hulls was especially urged.

Research on the utilization of chemical cotton and its derivatives.

To a large degree the research on uses of purified linters is being conducted by the industries which use it as a chemical raw material, and much of the work described under Present Research in this section will doubtless be continued.

9. Research on rayon: For use in rayon manufacture, cellulose must have certain characteristics. (1) A broad investigation of the characteristics of all available types of purified cellulose, whether from linters, from wood pulp, or from agricultural wastes, has been advocated, correlating the specific characteristics which are desirable in making viscose, acetate, and cuprammonium rayon with the source and the method of isolation or purification of the cellulose. (2) A need for dependable figures on relative processing costs of various types of cellulose was mentioned.

(3) Suggestions relative to wider uses for rayon: Many of the specific suggestions duplicate those given for cotton lint. (1) Further investigation of textile uses, particularly wider and more satisfactory uses for staple fiber; (2) a method for increasing the permanency of the resilience of staple fiber; (3) new methods of fabricating rayon; (4) further study of its suitability for special uses, such as artificial leather, insulation, and plastics, and wider applications for cellulose sheets and sponge.

10. Research on chemical derivatives of cotton linters: Suggestions include (1) Further study of lacquers, especially to improve strength and flexibility; (2) research to reduce the sensitiveness of cellulose acetate to moisture and to determine its value in windows and hot-house sash; (3) a broad study of various esters and ethers for films, lacquers, stiffening, and waterproofing finishes for cloth and other uses.

11. Topics mentioned for research were the condensation reactions between cellulose and various phenols and polybasic acids, which may result in new types of plastics, and hydrolysis or reduction at high temperatures and pressures. Other lines of work of this general type are discussed more fully in the section on Cellulose.

WHOLE COTTON

It has been suggested that attention be given the following: The cultivation of cotton for the purpose of utilizing the entire plant for cellulose; the use of this whole cotton in pulp, paper, and wallboard and in the preparation of alpha-cellulose for chemical conversion and subsequent use in rayon, films, and plastics; and the utilization of the noncellulosic byproducts, such as the oil.

CELLULOSE

Cellulose may be regarded as the carbohydrate skeleton of practically all plant life. Industrially, cellulose has great importance as a raw material, whether obtained as the primary product of an industry, such as fiber from the cottonseed, bast from the flax stalk, and wood pulp from forest trees, or from the byproducts of other industries, such as linters from cottonseed-oil mills, bagasse from the cane-sugar industry, and cereal stalks and straws from the production of grain.

Many familiar materials are practically pure cellulose or are derived from cellulose, for example, cotton and rayon textiles, many kinds of paper, transparent films, plastics, and lacquers.

Since all vegetable fibers are cellulosic, a survey of research on this basic component has been carried on in connection with the survey of research on the fibers themselves.

The different types of cellulose obtained from various kinds of plants are not always interchangeable in respect to their utility. Chemically, however, the molecule in each case is essentially the same. It consists of a long chain of glucose units, up to several thousand, chemically united in a uniform and regular way.

Ten years ago the preliminary chemical and X-ray evidence, together with the determination of the molecular weight of cellulose derivatives by the physical methods usual for crystalline compounds, led many to conclude that the number of glucose units in the individual cellulose molecule was small, the number reported by various investigators ranging from 1 to 6. More refined chemical investigations caused this view to be almost entirely abandoned in favor of a much larger molecule, estimated to consist of at least 170 to 200 glucose units arranged in the form of a chain. Today perhaps the predominating tendency is to consider the cellulose chain as including 3,000 to 3,500 glucose units. The development and reinterpretation of physical measurements, such as osmotic pressure, viscosity, and sedimentation constants in the ultra-centrifuge, have been largely

responsible for the tentative acceptance of this high figure. A cellulose molecule, if stretched out straight, would thus be long enough to be easily seen with the microscope. A cross section of it, however, would be far too minute for this even with the best instruments.

X-ray studies of cellulose show that the individual glucose units form a lattice, which varies in perfection in different samples. The individual chains are apparently organized in regular, parallel array, while the submicroscopic micelles or crystallites are separated by regions in which the arrangement is random and the structure more porous. The results of X-ray studies, together with the behavior of cellulose toward polarized light and swelling agents, indicate that the crystallites, the more random regions, and the porosities are all of colloidal dimensions. When dispersed, cellulose and its derivatives form colloidal solutions.

Celluloses of different origin may differ in the nature and amount of their noncellulosic material, carbohydrate and otherwise, as well as in the average number of glucose units in the molecule. Viscosity and ultra-centrifuge data, for example, indicate that native cotton cellulose may have a chain of 2,500 to 3,500 glucose units; isolated wood pulp, 1,000, with the individual lengths differing rather widely from that average; and viscose, 250 to 350. In addition, cellulose samples may differ in the arrangement of molecules in the micelles, and that arrangement, together with the colloidal character, may be extensively modified by physical treatment. Since all these factors greatly affect the physical and chemical properties of cellulose and its derivatives, the possible variations in cellulosic products are numerous, and the opportunities for research, both fundamental and applied, are great.

PRESENT RESEARCH

The radical change in theories regarding the structure of cellulose during the last decade has created many new problems and suggested possibilities with which current research is naturally concerned. Much of this research has the object of giving precision to conceptions which are vague or supported by insufficient evidence. Although the greater part of cellulose research work must actually take account of possible changes in the cellulose molecule and in micellar structure, in the following list the individual research items are grouped under the head in which there is the most interest.

The cellulose molecule.

1. Research on the size and structure of the cellulose molecule: Some consider that the cellulose molecule consists of about 200 glucose units. If this is true, the much higher values deduced from viscosity and ultra-centrifuge data probably indicate a loose association or agglomeration of cellulose molecules in solution. To explore this possibility, studies on the viscosity of cellulose cuprammonium solution are being extended, together with work on the relationship between the degree of dispersion and the viscosity of viscose solutions. Other methods of attacking this problem are also being studied.

2. Hydrolysis and degradation of the cellulose molecule: Other researches center around the possibilities of breaking down or otherwise modifying the cellulose molecule. These include (1) the effect of hydrogenation, (2) the nature of the materials produced by hydrolytic agents, (3) the effects produced on individual glucose units of the

chain by oxidants, (4) subjection of cellulose to "geophysical" temperatures and pressures similar to those involved in the formulation of coal and petroleum, to discover whether or not cellulose is the precursor of these fuels in nature.

3. Reactions of the hydroxyl group: The chemical reactivity of an important component of the glucose unit, namely, the hydroxyl group, is being studied. These investigations include (1) the relative ease with which the individual hydroxyl groups in the glucose residues may be nitrated, acetylated or deacetylated; (2) the correlation of physical and chemical properties of cellulose and study of the relationship of chemical composition to the physical properties of the esters; (3) the reaction of cellulose with formaldehyde; (4) the mechanism of the alkaline decomposition of the nitrate; (5) etherification and esterification reactions.

The micellar structure.

In this group of studies the main interest lies not so much in the behavior of the cellulose molecule as in the properties of bulk cellulose, regarded as a colloidal complex of capillary channels in oriented or partly random arrangement. At present there are three broad views regarding the details of structure. According to the first, the individual chains are organized for the most part in regular parallel array in the direction of the fiber or in the direction of tension during regeneration (as in a filament of viscose rayon). These discrete, elongated, submicroscopic micelles or crystallites are separated by regions in which the organization is less perfect. The second view differs from the first in that the submicroscopic micelles are thought to blur into the surrounding more random regions and individual cellulose chains, and to run through two or more micelles at various points along their length. According to the third view, the discrete micelles or particles are of microscopic rather than submicroscopic dimensions and are embedded in a matrix the physical and chemical properties of which are different from those of the particles themselves. It is not surprising, therefore, to find several studies in progress on fiber structure, carried out by chemical, ultra-microscopic, fluorescent, and X-ray methods. These include:

4. Studies on the behavior of cellulose in rays lying between the ultraviolet and X-ray wave lengths.

5. Studies on the electrophoretic behavior of cellulose and its derivatives.

6. Investigations to determine the change in moisture absorption with various pretreatments.

7. Studies on the nature of the absorption of dyes and on the general colloidal character of cellulose and its derivatives.

8. Studies on the fractionation and separation of the longer and better oriented micelles from shorter and more poorly oriented ones by selective extraction with sodium hydroxide or calcium thiocyanate, or by partial acetylation and extraction with acetone or acetic acid.

9. Studies on the absorption of a heavy metal from a nonhydroxylic solvent by the internal surface of cellulose fibers.

10. Studies on the chemical hydration of cellulose.

SUGGESTED RESEARCH

Some of the following suggested research projects are concerned chiefly with the cellulose molecule itself or with the micellar structure, while others, listed under general studies, are concerned with both.

Research on cellulose molecule.

1. Size and structure of the cellulose molecule: The suggestions include (1) research on the chemical constitution of cellulose, on chemical differences between cellulose from various sources, and on the colloid chemistry of cellulose and its derivatives; (2) extension of studies with the ultra-centrifuge; (3) the relationship between viscosity, rate of shear, and orientation in cellulose dispersions, using X-ray and optical birefracton methods with soluble derivatives containing atoms substantially heavier than oxygen or carbon.

2. Hydrolysis and degradation of the cellulose molecule: It has been recommended that particular attention be paid to the oxidation of cellulose and the mode of attack upon the glucose units affected, as well as to photochemical degradation, which is an important factor in the gradual loss of strength of cellulose and its derivatives.

3. Reactions of the hydroxyl group: The glucose units of cellulose contain one primary and two secondary hydroxyl groups. Studies are suggested on (1) the relative rates of reaction of the different hydroxyl groups; (2) reactions of cellulose in nonaqueous solvents, such as liquid ammonia, as the unusual reactivity of some of the compounds prepared in this way may render them particularly valuable; (3) the effect of chemical structure on the physical properties of cellulose derivatives, such as the acetate; (4) the possibility of preparing derivatives containing primary valence cross linkages between adjacent cellulose chains; and (5) the possible conversion of linear cellulose chains into derivatives having a crinkled or a flatter helical arrangement, which might have greater elasticity.

The micellar structure.

4. Optical methods: More liberal use of X-ray and spectrographic methods has been advocated, together with a greater application of the principles of colloid chemistry and the replacement of selected hydroxyls in fibrous cellulose by an atom considerably heavier than carbon or oxygen to facilitate X-ray investigations.

5. Topochemical studies: It has been suggested that new methods for estimating that fraction of the total hydroxyl groups and glucose units in the more porous regions and on the surface of the cells would form a valuable guide in studies on absorption and on the kinetics of heterogeneous reactions.

6. Effect of micellar and submicellar structure on reactivity: The minute structure of cellulose aggregates, either at the micellar level or lower, has a profound influence on chemical reactivity, particularly oxidation and esterification. Such old and well-known processes as mercerization, which drastically affect this minute structure, have in the main been studied only empirically. It is suggested that a study be made of the mechanism of this action and also of the effect of "activating" agents in undoing the mercerizing effect.

7. Swelling phenomena: The effect of absorbed water vapor or of liquid water in causing swelling and softening of cellulosic aggregates

and the more profound change known as hydration are only imperfectly understood. Since many conceivable uses for cellulose articles are at present closed because of its undesirable sensitiveness to water and other liquids, this field has been suggested for study. Specific studies suggested are an investigation of the degree of penetration of various liquids into the submicroscopic structure of cellulose aggregates and the application of the results obtained to the waterproofing of fibrous cellulosic articles, to the use of cellulose as a filler in plastics, to hydration of pulp in paper-making processes, and to the use of various types of cellulose fiber in nontextile sheets.

8. Cellulose dispersions: The dispersion of cellulose in the form of viscose and the regeneration of the cellulose as rayon filaments face many unsolved fundamental problems, besides the more practical ones discussed in the section devoted to rayon. It was recommended that more attention be given to the dispersion of cellulose in alkaline media, and that some of the older work be repeated with the assistance of all the newer techniques for the elucidation of molecular and micellar structure.

General studies.

9. Phytosyntheses and phyto-genetics: The natural synthesis of cellulose and of the noncellulosic substances that accompany it in plant tissues was recommended for investigation. Specific problems suggested for study are the differences in length of the chain, regularity of micellar arrangement, and complexity of fiber structure of different parts of the same plant and different species. This work should be closely correlated with that of geneticists and plant breeders.

10. Fundamental differences between cellulosic fibers from different plants: A broad study is needed of the fundamental characteristics of each member of the group of cellulosic fibers. When the factors which determine the character of a cotton fiber and differentiate it from an isolated wood or flax fiber are thoroughly understood, it should be possible to develop more desirable characteristics. It is suggested that such a study cover (1) the microscopic, micellar, and molecular structure; (2) the distribution and character of noncellulose components; (3) all the pertinent physical properties of the fiber itself, both in the original plant tissue and in the isolated and variously modified forms in which it is used; and (4) an analysis of those factors of gross or minute structure which determine the strength, stretch, and pliability of the fibers. The study under (4) is especially important.

11. Analytical methods: The chemical purity and reactivity of cellulose are now determined by means of certain tests (copper number, chlorine number, viscosity in cuprammonium solution, and alpha-, beta-, and gamma-cellulose content), which are almost wholly empirical. It was suggested that these tests be correlated with molecular and micellar structure, and with the content of known impurities or degradation products, in order to increase their usefulness and their significance.

12. Diffusion of various liquids into cellulose fiber: The important chemical reactions of cellulose are always complicated by the structure of the cellulose fiber. For instance, when cellulose is nitrated the sulfuric and nitric acids and water in the nitrating mixture diffuse through the structure at unequal rates, and the resulting product is a mixture of different compounds. It was suggested that an investiga-

tion be made of diffusion processes and osmotic effects and of the colloidal behavior of cellulose in a wide variety of reactive and inert liquids in order to improve the control of such commercial processes as nitration of cotton.

13. Fundamental industrial problems: In spite of centuries of practice and technological improvement, spinners of cotton and other plant fibers and manufacturers of paper are still unable to give to their products more than a comparatively small fraction of the aggregate strength of all the individual fibers, which is even less in comparison with the aggregate strength of all the cellulose chain molecules. Although this field has been investigated extensively, it has been suggested that a combination of fundamental knowledge of structure, thoroughgoing mathematical and dynamic analysis of the problem, study of the cause of failure of broken threads or sheets, and technological experimentation may lead to important advances in the use not only of cellulose fibers but also of wool and other animal fibers.

FLAX (FIBER)

Flax will grow over most of the United States, but it is raised principally in Minnesota, the Dakotas, Kansas, California, and Oregon. In all these States, except Oregon, it is grown for flaxseed and the fiber is a byproduct. In Oregon another variety of flax is grown for its linen fiber and the seed is the byproduct. The subject of flax fiber will, therefore, be considered in two divisions, "fiber flax" and "linseed flax." The research on each, as well as the suggestions, may be considered together, since that which is applicable to the one is generally applicable to the other. Research on flaxseed and linseed oil is discussed in the section on oil seeds and crops.

FIBER FLAX

About 40 million dollars' worth of linen and 2 to 3 million dollars' worth of fiber are imported annually into this country. Only about \$200,000 worth of fiber is raised here. The tall, nonbranching variety of flax cultivated for fiber will grow in many parts of the country, but about 80 percent of that grown here is produced in Oregon, where its cultivation on 5,000 acres is sponsored by the State flax commission. If imports of flax fiber and linen were eliminated and if our domestic demand for linen continued at present levels, it would take 125,000 acres to raise enough flax fiber to supply these domestic requirements. With crop rotation, about 500,000 acres of suitable land would be necessary. This acreage is available in the Willamette Valley in Oregon. The Oregon linen fiber now amounts to about 400 to 500 tons annually. It is of good quality and is used largely for the manufacture of linen thread and twine.

The average yield of flax in Oregon is about 1.65 tons per acre. From this are obtained 230 to 300 pounds of linen fiber and 100 to 130 pounds of tow and pullings ready for spinning, 250 pounds of stock feed, 500 to 600 pounds of seed, and a residue of shive. The flax is pulled mechanically and retted by bacteria. The fiber is obtained by mechanical scutching and hackling. For further development the industry needs scientific research to lower the processing cost and to

devise uses for the byproducts, such as the shives which are now used for fuel.

LINSEED FLAX

The variety of flax raised for its seed is generally a short, many-branched plant bearing a considerable quantity of seed. It is unsuited for the production of a long linen fiber such as is obtained from fiber flax. This variety of flax is allowed to come to maturity in order to obtain the largest yield of seed, and this tends to toughen the woody part of the plant so that the bast fiber is more difficult to obtain.

The linseed-flax straw fiber is mainly a wasted byproduct of the seed-flax industry, and the amount of flax straw available varies directly with the quantity of flaxseed produced. It is difficult to estimate accurately the quantity of fiber annually available. However, the straw-to-seed ratio is approximately 2 to 1, and about 80 percent of the flax is raised in concentrated areas, so that it is easily accessible to markets. The crude bast fiber content of the straw ranges up to about 20 percent. Based on these figures the quantity of fiber available annually in the last 20 years has varied from about 275,000 tons in 1924 to about 50,000 tons in 1936. The average quantity of fiber available annually for the 10 years ending in 1930 was approximately 170,000 tons. However, since that time the quantity of fiber available has fallen off to an average of 80,000 tons annually, for reasons that are discussed in the section on flaxseed.

Small quantities of flax straw are now used commercially for tow making, paper, and semiflexible sheets for insulation, but the demand is less now than in former years. There is also a well-developed industry based on the manufacture of flax-straw rugs. Commercial utilization of flax straw in 1924 amounted to about 200,000 tons (fiber equivalent, 40,000 tons) but in 1937 was only about 10,000 tons (fiber equivalent, 2,000 tons). Therefore, at the present time there is being wasted about 97 percent of the flax fiber available, or approximately 75,000 tons. However, because of inaccessibility to markets, presence of weeds in the straw, and other undesirable factors that affect the straw value, it is believed that it would be more conservative to calculate only half this tonnage as actually available for possible utilization.

Although this fiber is not as long or as strong as the fiber generally used for linen, it is a useful material, and if it can be obtained cheaply enough it may be used for coarse linen cloth, for rugs, or in the manufacture of cigarette paper; it is particularly suitable for the latter use because of the special characteristics of the fiber. About 5 to 6 million dollars' worth of cigarette paper is imported annually.

Linseed fiber is, then, a potential source of supply for a very large amount of useful fiber. This raw material is now mostly wasted.

PRESENT RESEARCH

Present research on flax has three objectives: Agronomic research on varieties, methods of freeing the fiber from the shive, and new uses for the fiber or for the byproducts. Studies are being conducted on:

Agronomics and genetics.

1. Breeding of disease-resistant and other varieties of flax in order to increase the acreage upon which production would be feasible, thereby increasing the supply of oil, fiber, and byproducts.

2. Breeding with the object of improving the quality and yield of oil and fiber.

Harvesting and decortication.

3. Development of machines for pulling the flax in the field and of deseeding equipment for removing the seed. The problems relative to harvesting (pulling) the fiber flax seem to have been partially solved.

4. Further development of a method of harvesting seed flax which rolls the seed out and leaves the straw long instead of cutting it up during the threshing operation. This method is already being used and promises a source of linseed-flax fiber of greater length than has been previously available.

5. Development of decorticating machines for freeing the fiber from linseed straw both before and after retting.

6. Use of machines for breaking the flax after it has been retted and of turbine scutchers for removing the shives from the fiber. Both types of equipment are now available. The mechanical scutching and hackling of retted flax can be accomplished satisfactorily except that the percentage of tangled waste tow may be too high.

7. The decortication of green flax and subsequent cutting into short lengths after chemical treatment.

Retting.

8. Retting of submerged flax fiber by the use of variations of bacterial retting, including pure cultures, and by enzymatic preparations: The work on bacterial retting has included close control of conditions in tanks and fundamental studies on the course of retting and on changes in free acids, esters, and salts during the retting period. A double ret is said to have advantages over a single ret in the production of fine fiber.

9. Unsubmerged retting of flax ("dew-retting"), including the application of the principle of the trickling-filter to racks of flax and an attempt to field-ret flax straw by allowing it to lie in the field for a period after cutting.

10. Chemical treatments with and without pressure treatment to "chemically ret" both varieties of flax. This has been successful only when the flax has been partially reduced to its ultimate fiber. This fiber, which is about as long as cotton, has been spun experimentally on cotton systems, both with and without the addition of cotton fiber, and the thread utilized in the production of fabrics. The fabrics have been submitted to use tests. This reduction of flax to a short fiber is termed "cottonization," and the process is being extensively studied both here and abroad. European countries with a large supply of flax tow waste have studied it particularly for the purpose of replacing cotton. The fabrics obtained have no great advantage over cotton textiles.

Utilization.

11. Investigation of the use of purified seed-flax fiber tow for use in making cigarette paper. This is apparently a commercial possibility, although no data are available.

12. Mixing of the shorter fibers with staple rayon to produce novel fabrics.

13. Substitution of flax tow for hair and similar binding materials in the production of asphaltic roofing.

14. Investigation of linen fiber as a substitute for cotton waste in packing journals on freight cars.

15. Search for other new uses for the fiber.

16. Experimental work on the use of the whole flax stalk as a paper-making or insulating material. This has been started with some success.

17. Submission of finished materials, such as textiles and linen paper, to use tests and to the action of various reagents in order to determine their proper fields of usefulness.

SUGGESTED RESEARCH

Most of the suggestions received relative to research on flax fiber have been concerned with methods of reducing the processing cost of obtaining the fiber. It should be noted that there is a distinct difference in the problem of freeing the fiber for use in spinning, where length is a necessary factor, and for use in paper, where fiber length is of minor importance.

Agronomics and genetics.

1. By selective breeding, a flax variety should be developed which could be more readily decorticated.

2. Agronomic research should be done to adapt the flax plants to different soils and particularly to develop drought-resistant strains.

3. The influence of environment on the quality and yield of both seed and fiber should be studied, as well as the effects of soil characteristics, fertilizer treatments, and cultural methods on the mineral content of the plant and on the character of the fiber produced.

Harvesting and decortication.

4. Pulling machines should be further studied in order to cut the costs of pulling.

5. Deseeding machines should be very carefully studied with the object of lowering the cost and improving the cleaning and arrangement of the straw.

6. Breakers for breaking flax straw after retting should be studied with the object of developing a process that will cause less damage to the fiber and make possible a more complete removal of the shives in the scutching operation.

7. Mechanical decortication of flax should be studied with the object of securing a better fiber at a lower cost. The possibility of producing a simpler machine which might be used partially to decorticate linseed-flax straw on the farm should be studied. Such a machine would enable the farmer to produce a crude tow to be sold for further purification, thus providing him with spare-time work, saving hauling charges, and leaving the shive on the farm.

8. Decorticating rollers might possibly be combined with a type of harvester that does not shred the straw when producing seed and tow.

Retting.

9. Present studies on enzymatic, bacterial, and "chemical" retting should be extended with the object of cutting costs by rigid and scientific control of conditions.

Utilization.

10. Further uses for flax fiber in paper making, especially methods for purifying linseed fiber for use in cigarette paper, should be investigated.

11. The economics of the use of flax fiber in competition with linen rags in the manufacture of high-grade linen paper should be studied.

12. The utilization of the linseed fiber for new textiles has possibilities which should be investigated. Spinning of "cottonized" flax and the use of the fiber in rugs has been accomplished. A survey of the possibility of spinning the coarse tow into dish toweling or sacking materials to replace imported fiber should be made.

13. A need exists for studying the value of fine fabrics that can be made from the different species of fiber flax that may be grown here, as well as the problems that would arise in producing acceptable fabrics comparable to those now imported.

14. The possibility of replacing certain imported fibers with flax-fiber tow should be studied.

15. Processing costs may be cut by developing methods of utilizing the byproducts. Studies should include extraction of wax from the shives and the utilization of shives for cellulose, insulation, or any of the other uses for which a collected agricultural waste is suitable (see Agricultural Wastes). The use of the shives as a feed base (the linseed shives contain 3 percent fat and 7 percent protein) has been suggested. In this connection the possible presence of prussic acid or other toxic substances should be considered.

Fundamental research.

16. A broad and unified study should be made of the morphology and physiology of flax, particularly the fiber formation.

17. A census of the minor constituents such as the pectins is suggested.

18. Fundamental investigations of the characteristics of the cellulose produced, using the methods suggested in the section on Cellulose, may throw light on many obscure problems in the production, processing, and use of this fiber crop.

HEMP

The word "hemp" is ambiguous in that about 30 different fiber plants, including the Manila hemp and sisal hemp, are often loosely referred to by this name. The common variety of American-grown hemp is *Cannabis sativa*. The plant grows well in the United States, attaining a height of 3 to 20 feet and under favorable conditions yielding 800 to 1,000 pounds of fiber per acre. In former years the production of hemp fiber was a flourishing domestic industry, the State of Kentucky alone producing 75,000 tons in 1859. In 1937 only 640 tons were produced in this country, mostly in Wisconsin. Imports were 778 tons, valued at \$221,330. Hard fibers such as Manila hemp and sisal have nearly replaced sativa hemp for ropes, cable, and coarse cordage, being better adapted for these purposes; and jute, although weaker, has replaced it in burlap bagging, etc., on a cost basis.

The hemp problem does not lie in growing and preparing the fiber but in obtaining a satisfactory market. In principle, the hemp crop is one of the best economic sources of long fiber available in this country. If the seed is allowed to mature, however, the fiber is not good,

and furthermore, the male plant dies before the female plant, so that the mixed fiber is uneven. The plant is cut by machine and allowed to dew-ret on the ground, after which it is collected in stacks and sold to the hemp mill. The mill dries the stalk and removes the fiber in a "hemp brake" for sale as cordage. A useful oil may be extracted from the seed, and a considerable quantity of hemp seed has been imported both for oil and for bird food.

Unfortunately, the hemp plant produces a narcotic drug known variously as marihuana, bhang, or hasheesh. The misuse of this narcotic has caused the passage of the Federal Marihuana Act, which forbids the growing of hemp except under Federal supervision. These restrictions have caused the fear that hemp, which is a "critical" material of national defense, may be entirely eliminated as a domestic product. As a result of the Federal Marihuana Act, research has been greatly stimulated on the chemistry of the alkaloidal constituents of the plant and on the attempt to produce a variety with no substantial content of marihuana resin.

PRESENT RESEARCH

Research on hemp now under way has the following objectives:

1. Reduction of narcotic content by genetics: Agronomic research is centered at present on the attempt to produce a variety of hemp that will contain only negligible amounts of the marihuana resin. The work on this is quite promising since some plants appear to produce very small quantities of the resin.

2. Production for seed and fiber: The possibility of producing hemp as a seed or fiber crop in various sections of the country is being studied. Breeding studies are being carried out with the object of producing a variety of hemp suitable for growing both seed and hemp. This necessitates a variety in which both male and female plants come to maturity together or in which the two sexes are combined in the same plant.

3. Use in paper: The use of hemp fiber in the manufacture of cigarette paper has been tried with excellent results. Commercial development is under way. Cigarette paper should furnish a quantity market for hemp as soon as the marihuana problem is solved.

4. Improved methods of retting. The technology of hemp retting is being studied.

5. Production of better fiber by cottonizing: The production of a short spinnable fiber by "cottonizing," both with chemical treatment and with hydrolytic enzymes, is being further investigated.

6. Increased knowledge of properties of marihuana: Studies on the isolation, characterization, constitution, and other chemical and physical properties of the marihuana drug are being carried on.

SUGGESTED RESEARCH

Suggested subjects for further research on hemp and marihuana are:

1. Production: It has been suggested that a survey of hemp production be made with special reference to lowering the cost, both by improving harvesting and decorticating methods and by finding uses for the byproducts. It is particularly desirable that hemp production be encouraged as a measure of national defense.

2. Use in paper: The use either of the whole hemp plant or of the fiber in the production of special thin, strong papers should be investigated.

3. Byproducts: The use of the collected hurds either as a source of pure cellulose or as a filler for plastics has been suggested.

4. Retting: The physical conditions and the cost of water-retting of hemp should be studied. It is considered that improvement in the quality and value of fiber would justify water-retting rather than the dew-retting now practiced.

Marihuana.

5. Agricultural phase: The proportion of plants containing appreciable amounts of marihuana and the effect of climate on its production should be determined. It is known that alkaloid production in general is less in northern latitudes. The effect of degree of soil acidity, of fertilizers, and of other factors on marihuana content, fiber quality, and seed production should be studied. Effect of seed treatment before planting should be studied with the object of producing plants that are inactive physiologically.

6. Chemical phase: The separation, purification, constitution, and uses of the alkaloid should be studied. Definite qualitative and quantitative methods of analysis should be established. The substance the presence of which is indicated by the Beam test should be investigated; it is not the alkaloid but a substance associated with it.

7. Pharmacological phase: The best conditions for a satisfactory bio-assay should be determined, as well as the animals best suited for experimentation. The fate of the alkaloid in the body and the pathological changes of the body under the influence of the drug should be investigated. The therapeutic use of the alkaloid should be studied.

RAMIE

Ramie, also known as rhea and as China grass, has been used in China as a source of fiber for 3,000 years. Ramie fiber has certain advantages over all other vegetable fibers. It has a very high tensile strength even when wet, is resistant to atmospheric changes and mildew, and is so lustrous and soft that it may be mixed to the extent of 20 percent with silk without greatly changing the appearance of the textile. On the other hand, no completely successful mechanical decortication method has been developed to obtain the fiber, the fiber is expensive to spin because of uneven lengths, and it possesses a natural basic fault in that it has a tendency to crack or break under torsional stress. Ramie is one of the strongest fibers when subjected to straight tension, but its brittleness, lack of resistance to flexing and low elasticity make it an extremely poor fiber for many commercial uses.

Although ramie fiber may be imported into this country at low cost, it has not achieved wide usage. The imports have varied from 2 million pounds (mainly for use in gas mantles) in 1919 to very little in 1932, about 105,000 pounds in 1936, and 50,000 pounds (value, \$4,829) in 1937.

The crop is difficult to harvest and prepare for market. In China, the mature stems are selected and cut, crushed, and cleaned by hand labor, one man producing only 2 to 6 pounds of crude fiber per day. For domestic ramie to compete successfully with crude imported ramie fiber, the industry would have to be completely mechanized.

In spite of the disadvantages outlined, the beauty of the fiber and the fact that the plant may be readily grown in this country, particularly in the Gulf States where recent yields have exceeded any reported in the literature, have stimulated research.

PRESENT RESEARCH

Research in this country has been principally along agronomic and mechanical lines, as follows:

1. Agronomic research: It has been shown that ramie may be raised with good yields in the Gulf States, particularly in Louisiana and Florida. The ramie may also be easily eradicated if a different crop is desired. The usual varieties of ramie do not mature all the stems at the same time and mechanical harvesting is therefore impractical. An attempt is being made to produce a ramie plant that will ripen uniformly and yield fiber that is uniform with respect to strength or fineness—properties very desirable in textile fibers.

2. Harvesting and decortication: Research is in progress on the development of harvesting and decorticating machines.

3. Retting: The enzymatic retting of ramie to produce a crude ribbon similar to imported China grass is being investigated.

4. Spinning: The spinning process is being studied with the object of spinning the uneven lengths of ramie fiber cheaply and efficiently.

5. Nature of fiber: Some fundamental research is being done, both on the character of the fiber and on its use as a source of very pure natural cellulose.

SUGGESTED RESEARCH

The following research on ramie has been suggested:

1. Fiber structure: Further physical, microscopical, and chemical investigations should be made on ramie fiber to determine the relation of joint structure and markings to its brittleness and inability to withstand flexing. It should be determined whether this is a basic fault common to all species of ramie or to what extent it results from the treatment received by the fiber during purification. In this connection, see the section on Cellulose.

2. Production and utilization: If the fundamental research on the value of the fiber is encouraging, further investigation should be made on the culture and production of ramie, development of decorticating machines, degumming operations possibility of scientifically controlled bacterial or enzymatic retting, chemical treatment of fiber, spinning problems, and cost factors in relation to foreign competition, with a view to establishing a ramie-fiber industry in this country on a sound basis.

BROOMCORN

Broomcorn is a variety of sorghum. It is unique among our agricultural products in that the brush has practically only one use—the making of brooms and whiskbrooms. The stalk is left in the field and some seed is used as feed, although it is not very palatable. The fiber is of poorer quality if the seed is allowed to mature. The more extensive use of brooms ordinarily is not stimulated by lower prices and the export market is decidedly limited, about 10 percent of the crop being exported.

The consumption of broomcorn is therefore so stable that any variation in supply causes tremendous fluctuations in price. The average price received over the last 12 years has ranged from a low of \$37 a ton in 1932 to a high of \$164 for the short crop of 1934. Last year (1937) the price averaged approximately \$70 a ton. This violent fluctuation in production and prices, and the heavy cash expense necessary in harvesting and preparing the brush makes broomcorn one of the most speculative of farm products.

The plant will grow over most of the United States, but commercial production is confined to relatively small areas in Oklahoma, Colorado, New Mexico, Kansas, Texas, and Illinois. About 325,000 acres of broomcorn are harvested annually. The yield of fiber ranges from 30,000 to 50,000 tons with a value of from 4 to 5 million dollars.

Broomcorn brooms have had to meet steadily increasing competition from vacuum cleaners, carpet sweepers, and push brooms made from tropical fibers. This decrease in use and the fact that any variation in supply causes great fluctuations in price combine to make it very desirable that another use for broomcorn fiber be found. Its high price as a raw material has in the past discouraged any research for other uses.

PRESENT RESEARCH

Present research on broomcorn is almost entirely an attempt to improve varieties by cross breeding with other sorghums. The following lines of work are in progress:

1. Experiments to develop broomcorn which will not turn red. The redness is due to the presence of a natural red dye which appears following any injury to the plant.
2. To develop broomcorn varieties with better brush; for example, without a center stem.
3. To breed dwarf broomcorn with a handle long enough to carry the brush out of the boot.
4. To grow a white-seeded variety with more palatable seeds.
5. To obtain a variety with no hair on the chaff, since the chaff on broomcorn causes extreme itching and sores on the skin of those working with it.

SUGGESTED RESEARCH

The following lines of research are suggested:

1. Investigate the possibility of using the tough wear-resisting fiber for weaving, as in hats or mats.
2. Develop a cheap method of bleaching the red discoloration of broomcorn. This discoloration does not greatly harm the broomcorn fiber but it lowers the market value greatly.
3. Establish the identity of the red dye produced by the plant as an aid to the research on bleaching methods.
4. Investigate the possibility of eliminating the fuzz on the seed chaff, which is so irritating to the skin that it is possible some toxic principle is involved.
5. Investigate the structure and composition of the fiber for the purpose of explaining the qualities of toughness, resistance to wear, and resistance to softening in water, all of which are much needed in cellulosic fabrics and structures of many kinds.
6. Study the utilization of broomcorn stalks, now mostly wasted.

MISCELLANEOUS FIBER PLANTS

In addition to the fiber plants already discussed, there are a number of others either produced in this country in small amounts or imported. These may be classed as hard fibers, soft fibers, and stuffing or filling fibers.

HARD FIBERS

The quantities and values of the 1937 imports of the hard fibers, which were used mainly for rope and cordage, were as follows:

	Tons	Value
Sisal and henequen.....	131,207	\$15,097,219
Abaca (Manila hemp).....	43,702	7,776,956
Istle (Tampico).....	10,727	967,061
New Zealand flax (<i>Phormium tenax</i>).....	105	14,383

Abaca is a tropical plant produced mainly in the Philippine Islands. New Zealand flax and sisal will grow in the southern part of the United States and in Hawaii. However, the expense of their production is believed to be prohibitive as compared with costs in, for example, Yucatan. A small amount of *Agave lecheguilla*, which produces Tampico fiber, has been grown in Texas during the past year or two. Both the yuccas and the sansevierias will grow in the Southern States, but production is mainly experimental and of no great commercial importance.

SOFT FIBERS

Of the soft fibers, flax and hemp have already been considered in individual sections of this report. (See pp. 105 and 109.) Jute will grow in the Southern States but probably could not compete commercially with low-cost jute imported from India. In 1937 imports of jute amounted to 91,961 tons, valued at \$8,729,897, and imports of jute butts to 26,648 tons, valued at \$1,133,116.

Numerous native and introduced plants produce good fiber, but it is doubtful whether the commercial production of any of them would be profitable in the United States. A few of these plants are as follows:

Sunn hemp, *Crotalaria juncea*.
 Caesar weed, *Urena lobata*.
 Colorado River hemp, *Sesbania macrocarpa*.
 Swamp milkweed, *Asclepias incarnata*.
 Indian hemp (dogbane), *Apocynum cannabinum*.
Hibiscus sp.
 Nettles, *Urtica* sp.
 Brotex, *Lavatera arborea*.

STUFFING AND FILLING FIBERS

In 1937 imports of kapok amounted to 11,710 tons, valued at \$3,372,649, and imports of crin vegetal amounted to 6,079 tons, valued at \$244,495.

Kapok will grow in the extreme southern part of Florida. Some of the palmettos produce a fiber similar to crin vegetal. In each

case the cost of production is an important factor preventing their development in this country. Spanish moss, an epiphytic plant growing on trees in the South, is used as a substitute for curled horse-hair. Collections of this plant amount to only a few thousand tons annually.

OTHER MISCELLANEOUS FIBERS

A small amount of fiber used in the manufacture of brushes is produced from the cabbage palmetto. Some slough grass is cut along the Mississippi River, dried, and used in matting manufacture.

Some esparto (131 tons in 1936, valued at \$15,213) is imported particularly for use as a paper-making material. Esparto and closely related grasses will grow in southern California. However, the domestic product cannot compete with the wild esparto, which covers 12 to 13 million acres in North Africa, where it is gathered by cheap labor.

About 10,000 tons of miscellaneous fibers of minor importance valued at \$784,000, including coconut fiber, sunn hemp, etc., are imported annually into this country.

PRESENT RESEARCH

In general, research on fiber plants is concerned with attempts to obtain the fiber cheaply and to utilize the byproducts. The following projects are active:

1. Studies to improve the retting of Spanish moss and to utilize the waste as fertilizer. An attempt has been made to isolate the organism responsible for the retting.

2. Investigation of the milkweed to determine the possibility of producing fiber from the stems and pods as well as other products and byproducts such as "rubber" latex. It is proposed to introduce milkweed for erosion control and to utilize the plant as source material for such products.

3. The use of brotex, *Lavatera arborea*, as a substitute for cotton has been quite thoroughly investigated both here and abroad, but the fiber has been found to be unsatisfactory.

SUGGESTED RESEARCH

The following suggestions have been received from those agencies interested in developing an organized program for the domestic production of fiber crops:

1. Both chemical and physical research should be carried out on all the fiber plants that may be grown in the United States, with the object of determining which ones may profitably replace fibers now imported and of establishing conditions under which they may be grown and processed in case of national emergency. (See also the section on cellulose.)

2. Both bacterial and chemical retting of Spanish moss should be investigated with the object of more quickly "debarking" the moss. A use for the byproducts should be found.

3. The chemical or mechanical production of pineapple fiber from pineapple leaves should be studied. At present pineapple fiber or "pina" is produced as a household industry in the Philippine Islands.

OIL SEEDS AND CROPS

The primary fats, oils, and waxes are derived from numerous sources and almost every country in the world contributes to their supply. They are derived from numerous plants and animals, from the fishes of the sea, and in Germany, at least, even from petroleum through the application of ingenious synthetic methods.

By far the greatest production of primary fats in the United States is derived from dairy cattle in the form of butter; from hogs in the form of lard; and from cottonseed, peanuts, soybeans, and corn in the form of oils. The 1937 production of each of these products was as follows: Butter, 1,624 million pounds; lard, 1,434 million pounds; cottonseed oil, 1,961 million pounds; peanut oil, 51 million pounds; soybean oil, 194 million pounds; and corn oil, 127 million pounds. In addition to these fats and oils which are primarily consumed in food products, in 1937 this country imported 411 million pounds of palm oil for use in the tin plate, soap, vegetable cooking fat, and oleomargarine industries; 634 million pounds of coconut oil (in the form of copra and oil) for use in the soap, oleomargarine, and other industries; 533 million pounds of linseed oil (in the form of flaxseed and oil); 175 million pounds of tung oil and 43 million pounds of perilla oil for use in the drying-oil industries (paints, varnishes, enamels, printing inks, etc.); 75 million pounds of olive oil for food and technological uses; and a large number of minor oils, many of which are imported in considerable quantities.

In order to provide some idea of the magnitude of the consumption of these products there is included herein the statistical report released on March 26, 1938, by the Bureau of the Census, United States Department of Commerce, showing the factory consumption of animal and vegetable fats and oils by classes of products for 1937 (table 5).

TABLE 5.—*Factory consumption of primary animal and vegetable fats and oils, by classes of products, for 1937*¹
[Quantities in thousands of pounds]

Kind	Total	Shortening	Oleomargarine	Other edible products	Soap	Paint and varnish	Linoleum and oil-cloth	Printing inks	Miscellaneous products	Loss including fouts
Total.....	4,993,914	1,651,841	324,905	395,684	1,475,756	457,785	102,763	26,213	351,766	207,201
Cottonseed oil.....	1,716,822	1,209,596	173,615	209,647	8,414	43	---	167	2,632	112,708
Peanut oil.....	67,515	58,141	2,880	1,097	820	---	---	---	92	3,715
Coconut oil.....	425,894	12,531	73,806	49,886	252,241	1,124	---	2	6,846	3,748
Corn oil.....	83,812	1,611	1,796	63,883	2,392	89	---	---	4,005	10,036
Soybean oil.....	178,516	90,798	31,793	15,530	10,274	16,143	834	80	3,038	9,926
Olive oil, edible.....	3,296	---	---	3,180	21	---	---	---	95	---
Olive oil, inedible.....	5,568	---	---	---	890	---	---	---	4,678	---
Sulfur oil or olive fouts.....	18,361	---	---	---	17,984	---	---	---	377	---
Palm oil.....	144,041	47	7,946	111,514	141,358	---	---	---	3,177	---
Palm-kernel oil.....	331,054	123,677	1,063	21,944	141,358	---	---	3	63	---
Babassu oil.....	42,063	127	14,606	11,294	14,308	---	---	---	333,303	---
Rapeseed oil.....	14,336	5,203	---	---	135	---	---	---	7,493	---
Linseed oil.....	375,220	1,522	---	---	1,359	267,184	68,151	20,342	16,510	152
Chinawood oil.....	120,378	---	---	---	---	105,731	7,198	2,762	4,687	---
Perilla oil.....	42,537	---	---	---	2	31,776	8,053	1,732	954	---
Castor oil.....	34,812	---	---	---	2,123	6,455	1,653	260	24,321	---
Sesame oil.....	37,667	29,269	1	3,435	2,944	---	---	---	81	4,937
Other vegetable oils.....	25,985	870	---	5,848	10,812	1,498	9	17	6,334	397
Lard.....	8,938	915	1,747	2,246	---	---	---	3	3,974	53
Edible animal stearin.....	38,711	29,664	3,375	4,696	321	---	---	---	14	19
Oleo oil.....	13,055	242	12,277	41	143	---	---	---	402	18
Tallow.....	68,896	66,278	---	1,593	---	---	---	2	712	168
Tallow, inedible.....	675,918	---	---	---	613,509	151	---	7	61,921	330
Grease.....	215,651	---	---	---	94,247	140	---	509	120,521	324
Neat-foot oil.....	70,196	66	---	---	65,136	15	---	1	3,553	10
Marine animal oils.....	---	---	---	---	123,879	27,277	16,765	298	4,967	15
Fish oils.....	229,077	21,284	---	---	---	---	---	---	37,966	1,608

¹ Preliminary report, Department of Commerce, Bureau of the Census, Washington, March 26, 1938.² Includes 30,708 thousand pounds reported by the tin- and terna-plate industry.

NOTE.—Data for oleo stock were not collected, hence the secondary products, edible animal stearin and oleo oil, are shown. The statistics were compiled from the quarterly reports of the several concerns to the Bureau of the Census, supplemented by special statements covering the entire year for those manufacturing more than one class of products. The total consumption in all industries for each item is the same as given in the bulletin for 1937, except for those vegetable oils for which the crude and refined products are indicated in the questionnaire, namely, cottonseed, peanut, coconut, corn, soybean, palm-kernel, palm, and babassu oils. For each of these a net consumption was arrived at by deducting from the total of both crude and refined consumed the quantity of refined produced.

Oils subjected to the process of hydrogenation or other treatment for special uses were reported as consumed in the products for which intended. For example: Oils treated for soap manufacture were entered in the column headed "Soap" and oils intended for edible purposes were entered in one or more of the columns covering edible products. The ultimate uses of the primary oils are designated in this way.

Fats and oils consist essentially of mixed glycerides of saturated and unsaturated fatty acids in various proportions. Besides these glycerides, oils and fats, especially in the crude state, contain a variety of minor components, including phosphatides, plant pigments, vitamins, sterols, hydrocarbons, higher alcohols, ketones, anti- and pro-oxidants, mucilaginous materials, and no doubt many substances not known at present.

Since lard and other animal fats are considered elsewhere in this report, the following discussion of oils, fats, and waxes is confined to those products which are derived primarily from oil-bearing seeds, although some of the chemical, physical, and technological problems are common to all, irrespective of their origin.

The major portion of research on oils and fats under way at the present time cannot be related to any one farm commodity but rather deals with fats and their constituents and derivatives without reference to origin. Such research, both fundamental and applied, is discussed in this chapter while that dealing specifically with a particular commodity is reviewed under the appropriate crop.

SEED-OIL RESEARCH

All of the oils or fats derived from seeds may be roughly divided into drying, semidrying, and nondrying groups depending on the kind and degree of unsaturation of their constituent fatty acids, or they may be classified as drying, edible, and inedible oils, depending on their uses. However, these are not rigid classifications since unsaturation is merely one of degree and intergrading is continuous, whereas many oils are used interchangeably in several categories. Despite the inexactness of these classifications, they are nevertheless helpful in considering the common problems of the various groups of oils.

Within a given classification, many oils are used interchangeably. For example, cottonseed, peanut, corn, soybean, and similar oils are used in various amounts in the production of vegetable shortening and oleomargarine. Also many oils are used interchangeably in the manufacture of certain kinds of soaps. In the field of drying oils similar interchange of oils occurs; and although no two oils have identical properties, by blending various oils finished products of similar properties can be obtained. The degree to which this interchange of fats and oils is possible depends on the knowledge, skill, and degree of technological development within a given industry.

PRESENT RESEARCH

Considerable research on oils, fats, and waxes is being conducted in various institutions and industrial laboratories. The projects are greatly diversified, and range from fundamental studies of the structure of the fat molecule through physiological investigations of the fate of ingested fats in the animal organism, to pilot-plant scale separation of derived acids and esters. These projects are as follows:

1. Study of the disposition of ingested fats and the nutritional value of individual fatty acids. The question whether fats are directly utilized or stored in the various fat depots of the animal, to be withdrawn as needed, is being answered by the application of modern research techniques. By the use of tagged (containing heavy hydrogen) fatty acids and by the application of absorption spectra, evidence

is being obtained concerning the fate of oils and fats in the animal organism.

2. Studies of the synthesis of various mono-, di-, and tri-glycerides and of certain of their physical and chemical properties, especially their melting points, heats of combustion and formation, optical rotation, solubilities, and migration of acyl groups.

3. Investigations of the low-temperature crystallization of the unsaturated fatty acids from various animal and vegetable fats and oils, and methods for their identification through the application of absorption spectra measurements.

4. An investigation of the enzymatic hydrolysis of synthetic and natural glycerides and specificity of various enzyme preparations to accomplish this reaction.

5. Studies of the nature and mechanism of oxidative rancidity from several different angles, including the effect of metals, pigments, light, and moisture, as pro-oxidants, and of phosphatides, tocopherols, sterols, vitamins, etc., as anti-oxidants.

6. Investigations of laboratory and pilot-plant vacuum distillations of fatty acids and esters and commercial production of highly unsaturated fractions of mixed acids.

7. Molecular distillation of fats and oils both for the purpose of separating the component glycerides and for the removal of sterols, pigments, vitamins, anti-oxidants, etc.

8. Work on the preparation of derivatives from fats, oils, acids, and esters. The addition of mercury acetate to ethyl oleate has been successfully accomplished and the product adapted as a specific weed eradicator. Reactions with liquid ammonia and special oxidation agents, such as lead tetra-acetate and periodic acid, are being studied. The preparation of hydroxy acids, ketones, and nitriles is being actively investigated, and a number of the products have been shown to have valuable properties as "doping" agents in extreme-pressure lubricants. Certain industrial laboratories are engaged in the study of metallic soaps, modified fatty acids, and anti-oxidants for use in extreme-pressure lubricants. Other laboratories are investigating animal and vegetable fats and oils for the production of special-purpose lubricants.

9. Experiments on the controlled hydrogenation of fats and oils, including a study of catalysts, carriers, promoters, etc.; also studies in the field of high-pressure hydrogenation of long-chain fatty acid esters for the production of related alcohols.

10. The refining of vegetable oils by means of absorption agents contained in packed columns followed by solvent recovery of the absorbed materials.

11. Standardization of the current analytical procedures for the examination of fats and oils and the detection of adulterants.

12. Investigation of the interfacial tension between pigments and oils and the development of methods for the determination and measurement of this property, and studies on mono- and poly-molecular films of fatty acids and oils, with especial reference to emulsions, etc.

13. Studies of methods for the production of short-chain fatty acids from longer-chain naturally occurring fats and oils, especially for use in the manufacture of hard-water soaps, and also on the general chemical conversion of both glycerides and fatty acids to more valuable industrial products.

14. The identification of fatty acids by the application of spectroscopic methods.

15. Investigation of yield, composition, properties, and possible uses of oils, fats, and waxes, especially those which are new or little known commercially.

16. Research on problems of the interchangeability of all fats and oils with particular emphasis on problems involved in planting, production, taxing, and trade agreements.

17. Studies on prices, competition, and interchangeability affecting the demands for oils by the soap, paint, and drying oil, oleomargarine and vegetable shortening, salad oil, and other industries.

18. Investigation of the food quality of fats including flavor, stability, shortening value, and general food uses.

19. Studies on the use of soaps to increase adhesion of bitumen for mineral aggregate and also for the more uniform dispersion of bitumen through soil particles in the treatment of roads.

20. Work on the physicochemical properties of detergents, wetting agents, and dry-cleaning agents, derived from fats and oils.

21. Work on the use of oxidized or polymerized oils as plasticizing agents for many purposes.

22. Investigations on the preparation and properties of the peroxides of fatty acids containing more than 10 carbon atoms. These peroxides are said to prevent development of rancidity in flour and to have germicidal properties.

SUGGESTED RESEARCH

The suggestions submitted for research on oils and fats were so numerous that it was thought inadvisable to attempt to list all of them. Those which pertain specifically to certain crops have been included in the appropriate section. Those which could not be so treated have been grouped under the general headings below. The subject matter of each paragraph is, therefore, a digest of all the suggestions more pertinent to the general topic listed than to any specific product. A brief introductory statement is included where necessary to make clear the reasons which prompted the suggestions.

Processing.

1. Pigments: In addition to the carotinoids which are closely related to vitamin A, vegetable oils contain varying amounts of plant pigments concerning the nature of which little is known. Since the control of color by means of bleaching is an important operation in the processing of vegetable oils and since the color of the finished product is a primary consideration in its salability, it is obvious that a knowledge of the kind and amount of the pigments present in crude and refined oils is of utmost importance to the processing industry.

2. Solvent extraction: The use of simple and mixed solvents has been successfully applied to the separation of various constituents and fractions from petroleum oil. Similar studies applied to vegetable oils doubtless would yield equally valuable results and should, therefore, be investigated both on a laboratory and pilot-plant scale.

3. Filtering and bleaching agents: A broad investigation of physicochemical behavior of various earths, carbons, and other refining, filtering, and absorbing agents no doubt would yield valuable information applicable to bleaching, refining, and similar technological operations in the vegetable and animal-oil industry.

Nutritional investigations:

4. Vitamins: Most oils and fats contain vitamins of one type or another and some oils are especially rich in these substances. For example, vitamin D is found abundantly in fish and animal liver oils and in butter, while vitamin E has been shown to occur in appreciable quantities in wheat- and corn-germ oils. Vitamin K, which has been found to be necessary to chickens for the prevention of anaemia, haemorrhage, and certain other pathological conditions, is known to occur in the mammalian liver fats. Although the presence of vitamin A has not been unequivocally demonstrated in any vegetable oil, most oils do contain variable amounts of carotinoids which serve as precursors of this vitamin. For example, vitamin-A-starved animals when fed carotene have been shown to store vitamin A in their livers. Also, if absorption spectra data can be trusted, the unsaponifiable matter from oils contains substances closely related to vitamin A. In view of these facts a very thorough investigation of the vitamin content of all domestic oils should be undertaken.

Applied investigations:

5. Insecticides: There has been an increasing utilization of various oils as insecticide conditioners. Recent research has indicated that certain chemical combinations of oils have high insecticidal value, and the oils alone in some cases are known to have some value as an insecticide, but possibilities of their application have not been adequately explored. Cottonseed oil, peanut oil, and corn oil all have possibilities of utilization in the insecticidal field, either directly as conditioners or in the manufacture of effective insecticides. Cottonseed oil and cottonseed-oil soap are known to have insecticidal value. When cottonseed oil is heated with sulfur, a chemical combination takes place and the resulting sulfurized oil and also the soap made from it have enhanced insecticidal value. The fatty acids derived from cottonseed oil may be used in place of acetic acid to combine with copper and arsenic to form products analogous to paris green, which are possessed of great insecticidal value and are much safer for application to delicate foliage. The possibilities of the development of cottonseed oil and cottonseed-oil soap products have not been adequately explored. Similar considerations are applicable to corn oil. It has been suggested that a program of research to explore the insecticidal possibilities of these plant oils be set up somewhat as follows:

(1) Constituents of plant oils, especially those of cotton, peanuts, and corn, responsible for the insecticidal action of these oils; their isolation; chemical and physical properties; and insecticidal action on various insects.

(2) The insecticidal value of soaps (made with sodium hydroxide, potassium hydroxide, triethanolamine, etc.) derived from these oils.

(3) Synthetics derived from these oils and their insecticidal value. Reference is made to compounds of copper, arsenic, and the fatty acids derived from these oils (compounds analogous to paris green); to compounds made by heating oils with sulfur; and to hydrogenated, dehydrogenated, acetylated, and halogenated derivatives of these oils.

6. Short chain fatty acids: With the exception of milk fat, no fat or oil is obtainable in sufficient quantity other than coconut and palm-kernel oils which contains sufficient short-chain fatty acids for the preparation of free-lathering soaps, powders, and creams. Since it is unlikely that any such oils can be raised domestically the only possibility of producing them in the United States is by means of synthesis or by degradation of longer-chain fatty acids. Lauric acid can be produced by splitting erucic acid, which is found in rape-seed oil. Acids of shorter chain length can be produced by degrading other unsaturated acids. The investigation of the economical production of short-chain fatty acids should be extended and a study made of their applicability to the production of soaps, detergents, wetting agents, and intermediates for plastics, artificial fibers, rubberlike materials, etc.

7. Impregnation of fabrics: An important field of investigation pertains to the possible development of flexible oil films for use in impregnating fabrics to be applied as coverings on electric wires; also films to be applied directly to wires. These films must have high dielectric strength, resistance to heat and moisture, and also must possess high mechanical strength.

8. Oil lacquers: The investigation of the development of oil lacquers through studies of improving the compatability of pyroxylin, cellulose acetate, and ethyl cellulose with vegetable oils doubtless would lead to enlarged uses of such oils.

9. Pharmaceuticals and cosmetics: Fats and oils are used as carriers and for other purposes in the pharmaceutical industry, e. g., sesame oil is used as a carrier for the sex hormones and lanolin for the preparation of ointments. Oils and fats are also used in considerable quantities in the cosmetic industry. For these purposes specific oils and fats of high purity are required. The investigation of many oils and fats, with a view to adapting them to these specialized uses, is needed.

10. Leather: The use of domestic oils no doubt could be extended through studies of their use in the leather industry, especially to replace imported coconut oil in fat liquoring and other operations. The use of vegetable oils blended with synthetic resins for finishing leather appears to be desirable.

11. Textiles: Studies should be initiated with the objective of substituting domestic oils for the olive oil used in the textile industry. The study of peanut and soybean oils for this purpose has been recommended.

12. Tin plate: A similar substitute for palm oil used in the tin-plate industry has been suggested. Such an oil might be produced by controlled hydrogenation of a domestic oil.

13. Rubber compounding: A study of various natural and hydrogenated oils for use as carriers for rubber pigments has been suggested.

14. Water-oil paints: It has been stated that a search should be made for nonyellowing oils for use as emulsifying agents for cold-water paints.

15. Protective coatings: General studies are needed on the adaptability of various domestic oils to the production of protective coatings, including paints, varnishes, oil lacquers, and baked finishes.

Fundamental research.

16. Origin: Although a number of theories have been proposed to account for the origin of fats and oils in plants, almost nothing is known concerning the method by which nature elaborates these substances in the plant cell or transforms them in the animal body. Consequently a study of these fundamental processes would seem to be most desirable, although such research would be most difficult and slow of fruition.

17. Structure and composition: Until quite recently fats and oils were considered to be composed of mixtures of simple triglycerides despite the fact that few unmixed glycerides could be isolated from them. Due to the work of a few individuals, mostly abroad, it is now known that this is not the case and that oils for the most part consist of mixed glycerides containing two or more fatty acids in each glyceride molecule. No more fundamental or important research in the field of fats and oils could be undertaken than an investigation of the composition and structure of the naturally occurring glycerides.

18. Sterols: Sterols are known to occur in the unsaponifiable fraction of many oils and especially so in the germ oils and soybean oil. Fundamental studies on the occurrence and nature of the sterols present in vegetable oils undoubtedly would provide much-needed information on these substances. (See the sections on Soybeans and Corn- and Wheat-Germ Oils for more specific suggestions.)

19. Alcohols, ketones, etc.: The unsaponifiable matter found in vegetable oils contains, besides sterols and vitamins, higher alcohols, ketones, and related substances concerning the identity, occurrence, and nature of which little or nothing is known. Investigation of these substances is much to be desired.

20. Synthesis: Considerable work has been done in the past on the synthesis of glycerides and the subject is being actively investigated. For fundamental studies of the properties of glycerides a supply of very pure products is required, and these can be obtained with assurance only by synthetic means. For the synthesis of the long-chain fatty-acid glycerides it is necessary to start with fatty acids which have been derived from natural glycerides. So-called neo-fats are now produced synthetically on a commercial scale by esterification of distilled fatty-acid fractions derived from the distillation of hydrolyzed natural fats. It is possible by this means to produce synthetic fats and oils of any desired degree of unsaturation and, therefore, adapted to specific uses. Synthesis of esters of polyhydric alcohols other than glycerine should be studied.

21. Distillation of glycerides, acids, and esters. Although both the molecular distillation of glycerides and ordinary distillation of the derived acids and esters are being investigated to some extent, nevertheless no such approach has been made or effort expended on natural vegetable oils as has been the case with petroleum oil. A fundamental physico-chemical investigation of the factors involved in the distillation of vegetable oils and their derived acids and esters should make possible far-reaching advances in the technology and use of these products.

22. Oil drying: It has been asserted that paint films, during the process of drying, evolve materials which affect photographic film emulsions. This effect cannot be attributed to the solvents but apparently arises from some product of the drying reaction. This

phenomenon should be investigated since it is important in the application of paints to interiors of industrial buildings, especially where photographic emulsions are produced. This phenomenon is typical of our lack of knowledge of the mechanism of film formation. Although a great deal of study has been devoted to this problem and numerous theories have been put forward to explain the phenomenon of drying, yet the whole process is obscure. A thorough study of the problem of film formation should be initiated, together with the closely allied process of heat bodying.

23. Phosphatides: Most vegetable oils contain phosphatides in various amounts. Soybean oil is especially rich in these substances. Despite the fact that considerable research has been conducted with these substances and many uses have been developed for the more or less crude product derived from soybean oil, nevertheless considerably more study of the occurrence, structure, and use of phosphatides is desirable.

24. Anti-oxidants: Most crude or virgin oils contain a substance or substances which protect them against oxidation. During the process of refining, these substances are removed or destroyed, with the result that the refined oil is much more susceptible to oxidation and tends to become rancid. Almost nothing is known concerning the identity or nature of these anti-oxidants, much less the mechanism by which they protect the oil against oxidation or their fate during refining. The same statement applies equally to pro-oxidants which are known to occur in certain oils. Since stability or keeping quality is of prime importance in refined oils, knowledge of the natural anti-oxidants is extremely important and should be a primary object of any program of vegetable-oil research.

25. Odorous constituents: Most crude oils and many refined ones possess characteristic odors and flavors which are often deleterious, especially from the standpoint of their use for edible purposes. Typical of such distinctive odors and flavors are those of peanut, soybean, and corn oils. Nothing is known concerning the identity and nature of the substances responsible for these odors and flavors, despite the fact that much money and effort is spent in attempts to remove them as completely as possible during the processes of refining and deodorization. It is obvious that a knowledge of the identity and nature of these substances would be most helpful in controlling their removal and thus enhance the value of the finished product.

26. Reversion: Closely related to oxidation and natural odor and flavor problems is one which, for want of a better term, is designated "reversion." Reversion is usually defined as the development of an off odor and flavor in an oil which has previously been refined, bleached and deodorized to produce a bland oil. These off odors and flavors have been variously described as fishy, painty, grassy, etc., and are more or less characteristic of a specific oil, some oils being especially susceptible to reversion. The problem of reversion is extremely important to the whole edible-oil industry and is in need of much study from the standpoints of the mechanism by which it occurs, the products which are formed, and means of inhibiting or eliminating its occurrence.

27. Enzymes: Many oils contain fat-splitting enzymes which in the case of crude oils often bring about the hydrolysis of the triglycerides to di- and mono-glycerides as well as free fatty acids and glycerol.

Since these free fatty acids must be removed during refining with resultant increased cost for processing and loss of oil, it is obvious that a greater knowledge of the nature and mode of action of these substances is not only desirable but of considerable economic importance.

28. Physical properties: Despite the importance of many of the physical properties of vegetable oils which are of the utmost importance, to the processing and consuming industries, little information is available concerning them or their variation with temperature and pressure. Such significant properties as viscosity, density, surface tension, dielectric constant, thermal conductivity, and solubility in organic liquids are known for but few oils and only for an extremely limited range of temperature and pressure. Even less is known about heats of combustion and formation, vapor pressures, and melting, setting, and transition points. Infrared, ultraviolet, X-ray, and Raman spectra data are likewise known for but few oils. All of these properties are badly in need of investigation since the derived data are most essential for the further extension of the uses of these materials. The physico-chemical approach to fat and oil problems has been becoming increasingly important in recent years and in the future will become even more so.

29. Analytical methods: Practically all of the methods in use today for analyzing and characterizing fats and oils are empirical rather than absolute. They have grown up over a period of years and have served the industry as a guide for buying and selling oils and fats but are of little value for determining the actual chemical composition of these substances. Many of these methods are known to give erroneous, or at best only approximate, information concerning the nature of a particular oil or fat. Perhaps the most important chemical property of a fat or oil is its degree of unsaturation, yet no universally applicable method of determining this factor has been devised. The determination of the amounts of saturated and unsaturated (solid and liquid) acids is at present laborious and the results are of dubious validity except under optimum conditions which are fulfilled by few natural fats and oils. The investigation of existing methods and development of more exact techniques of analysis are urgently needed in the field of fat chemistry. The development and application of micro-methods to fats and oils is especially in need of investigation.

30. Effect of chemical agents: From the viewpoint of fundamental chemistry as well as of technology, fats and oils need to be investigated with respect to their reactivity with other substances. Since many fats contain various groups of reactive double bonds as well as other points of attack by chemical and physical agents they form excellent raw materials for the preparation of new and unusual products. The literature contains isolated instances of attempts to study such reactions but much remains to be done before the field can be said to be completely explored.

Except for the bromo-derivatives little is known of the halogenated products. Much the same condition is true concerning the effect of oxidizing reagents other than nitric acid, potassium permanganate, atmospheric oxygen, and ozone. Even these studies have been confined principally to the fatty acids rather than to the glycerides.

The use of heat has been studied in polymerization reactions but little is known concerning the effect of pyrolysis and cracking of fats

and oils except in the case of castor oil and a few others. The effect of the application of the electric current is almost wholly unknown.

Some work has been carried out with respect to the action of sulfur and sulfur chloride and more recently of phosphorus on certain oils but little is known concerning the reactions which occur or even how to control them. The same applies to reactions with selenium, tellurium, arsenic, antimony, mercury, and their derivatives.

Perhaps the best known and technologically most important reactions of fats and oils with strong mineral acids relate to the use of sulfuric and hydrochloric acids. Some work has been carried out with phosphoric acid, and, as previously mentioned, with nitric acid, but much of value might be accomplished by studying the effects of other acids and their anhydrides.

Alkalies have long been used in refining operations and for saponification. Treatment with lime is an ancient practice and the ammonolysis of fats for the direct production of amides has been studied, but other alkalies including ammonia and amines should be more completely investigated.

31. Plastics: Fundamental investigation is needed of the reaction of oils, fats, and derived acids and esters with phthalic, maleic, adipic, and other anhydrides. Similar studies on their reaction with turpentine and other terpenes and unsaturated compounds in general are also needed.

32. Plasticizers: Valuable information could be obtained from a fundamental study of fats and oils as plasticizers. Hydroxylated, heat bodied, oxidized, and chemically treated oils and fats should be especially studied from this standpoint.

COTTONSEED

Cottonseed production naturally parallels that of lint cotton. Cotton is produced in all the States of the South.

During the period 1928-32, which was fairly typical, the total cottonseed crop averaged $6\frac{1}{2}$ million tons annually. The record crop of 1937 amounted to $8\frac{1}{2}$ million tons while that of 1938 was about one-third less.

The price received by farmers for cottonseed has been about \$30 a ton in recent years. However, it dropped as low as \$8.91, average for the year 1931, and during the 1937 season averaged only \$19.69 a ton. Cottonseed has returned the growers a gross income in the last two years of 141 and 130 million dollars, respectively. In more prosperous years cottonseed returned growers an income of about 200 million dollars a year.

Within the last 80 years cottonseed has changed from the position of an agricultural waste to that of the source of the most important vegetable oil consumed in the United States. The proportion of the seed production annually crushed in this country has increased from 5 percent in 1876 to an average of 80 percent for the past 25 years.

The highest production of cottonseed products was in 1926, when 6,306,000 tons of seed were crushed, producing 1,887,000,000 pounds of oil and 2,840,000 tons of meal. The average annual farm value of the cottonseed crushed for the 8-year period from 1928 to 1935 was \$88,366,000.

In 1937 cottonseed oil represented 26 percent of the estimated consumption of primary fats and oils in foods and food products in the United States. It was exceeded only by butter. In the same year cottonseed oil represented nearly one-third (1,716,822,000 pounds) of the total factory consumption of all primary fats and oils. Of this amount of cottonseed oil, over 90 percent (1,592,858,000 pounds) was used for the manufacture of shortening, oleomargarine, and other edible products. Only 8,414,000 pounds were consumed in the soap industry. Small amounts were used in the manufacture of paint and varnishes, printing inks, and miscellaneous products.

Besides oil, cottonseed furnishes oil cake or meal, linters, and hulls. The cake or meal is used almost exclusively for stock feeding, the linters as a source of cellulose, and the hulls as a filler in stock feeds, as a fertilizer, or as fuel at the crushing plants. Cottonseed hulls offer many interesting possibilities as a source of intermediate products for industrial utilization. (See Agricultural Wastes.)

PRESENT RESEARCH

Considerable research on the growth, production, and utilization of cottonseed is in progress at various State experiment stations and land-grant colleges and by United States Government bureaus. Various laboratories operated by the processors and consumers of cottonseed oil and meal likewise are carrying on research that is more or less fundamental to the industries concerned. A brief description of the nature of the reported research projects follows:

Agricultural research.

1. Genetic studies designed to increase the yield of protein and oil and decrease the gossypol content of cottonseed.
2. Studies on the effect of environment and other factors on the quality and composition of cottonseed.
3. Investigation of the effect of storage, handling, and deterioration on the amount and quality of oil and meal obtained from the seed.
4. Investigation of methods of sampling and analysis in connection with marketing, also of the relation of the variety of seed to the grade and composition of the cottonseed produced.
5. Determination of the physical constants and chemical composition of cottonseed from different sections of the United States.

Processing.

6. Studies on precooking of cottonseed meals prior to pressing, for the purpose of increasing the yield of oil.
7. Studies of the effect of time, pressure, and temperature on the quality and yield of oil and meal obtained from cottonseed.
8. Chemical studies of the processing of cottonseed oil and by-products for the purpose of improving the quality of the oil and reduction of refining losses.
9. Studies on the reduction of refining losses by first subjecting the raw oil to centrifugal clarification.
10. Investigations of the methods and costs in present oil-bleaching technique.

Utilization.

11. Investigations on the utilization of cottonseed oil to improve the food value of oleomargarine.

12. Investigations of the nature and cause of the flavor and stability of cottonseed oil and derived products.

13. Studies on the utilization of hydrogenated cottonseed press cake in the manufacture of auto tires, belting, and other rubber products.

14. Studies on refining, hydrogenation, and other treatment of cottonseed oil to produce a superior shortening for the baking trade, with particular attention to stability, color, and physical factors.

15. Investigation of the sulfonation of cottonseed oil for use as a spray and cutting oil.

16. Studies on the production of textile finishing oils from cottonseed oil.

17. Studies on the utilization of cottonseed oil as a soap stock.

18. Studies on the use of cottonseed-oil emulsions containing paradichlorobenzene for insect control.

19. Studies designed to improve the recovery of fatty acid from soap stocks.

20. Investigation of cottonseed meal as a source of vitamin B complex.

21. Investigation of the utilization of the pitch derived from the distillation of cottonseed oil fatty acids, which is now used for roof and similar heavy tar paints. This pitch contains insoluble sterols.

22. Studies on the extraction of cottonseed proteins for commercial utilization.

23. Studies on the extraction and utilization of gossypol from cottonseed meal, especially as industrial anti-oxidants and as insecticides.

Fundamental research in chemistry, physics, and technology.

24. Study of the organic nitrogen bases from the pyrolysis of cottonseed meal.

25. Microchemical studies of the oils, resins, and pentosans of the cottonseed.

26. Destructive distillation studies on cottonseed.

27. Study of the catalytic effect of various metals upon free fatty acid content, color, and flavor of refined oil intended for food uses.

28. Fundamental investigation of enzymes in cottonseed meal.

29. Investigation of the cause and type of variation in the protein, oil, and gossypol content of cottonseed; also an investigation of the nature and amount of the other chemical components present in cottonseed.

SUGGESTED RESEARCH

The following suggestions have been submitted as possible projects for investigation in the field of cottonseed utilization.

Agricultural research.

1. Extension of the present studies on the development of cotton varieties especially for the purpose of improving the yield and quality of derived oils and proteins.

2. Further studies on the pretreatment of cottonseed with sulfuric acid prior to planting for the purpose of removing linters and softening

the hull to permit better moisture penetration and germination of the seed.

3. Complete determination of the chemical composition of cottonseed upon the basis of species, variety, and strains, including the determination of gossypol and other compounds that may be important in nutrition.

4. More thorough study on the effect of commercial fertilizers and other fertility factors on the chemical composition of the seed.

5. Thorough study of the influence of physiological and ecological factors on chemical composition.

6. Studies of the deterioration of cottonseed in the field caused by exposure and by micro-organisms, enzymes, etc.

7. A comprehensive study of the effect of storage of cottonseed, including respiration during storage and effect of temperature, moisture content, etc., on the quality and yield of oil and meal.

Processing.

8. Studies to develop better methods of processing seed for the prevention of deterioration without changing the chemical composition or lowering the commercial value.

9. Engineering studies of the process of delinting cottonseed with a view to improving present machines and practices.

10. Research to improve methods of hulling, softening, pressing, and other treatments to increase the yield of oil.

11. Studies on methods of rehydrating excessively dry cottonseed from the Southwest prior to crushing, in order to increase the yield of oil.

12. Investigation of means for improving refining, bleaching, and deodorizing methods, with special attention to reduction in the cost of bleaching.

13. Study of the controlled hydrogenation of cottonseed oil, especially with respect to the type of catalyst used.

Utilization.

14. Studies on the blending of partially hydrogenated cottonseed oil with palm oil as substitutes for straight palm oil in the tin-plate, rubber, lubrication, and other industries.

15. General investigation of the stability of hydrogenated and unhydrogenated cottonseed oil, with special reference to extending its use in the baking and frying industries.

16. Investigation of the production and use of cottonseed oil fatty acids in the preparation of soaps, greases, and lubricants, and in the unhydrogenated state as a finishing and penetrating oil.

17. Further studies on the pyrolysis of cottonseed oil, meal, and hulls with special emphasis on the isolation, identification, and use of the products formed and particularly of the hydrocarbon fraction for use as lubricants.

18. Studies to improve the processes of preparing cottonseed flour for use in the human diet, especially for use in diabetic foods and to improve the texture and volume of bread.

19. Investigation of the use of cottonseed hulls in insulating materials and wall board, and for the production of furfural and other industrial products. (See Agricultural Wastes.)

20. Investigation of the composition and possible uses of the condensable constituents produced during the deodorization of cottonseed oil.

Fundamental research in chemistry, physics, and technology.

21. Determination of various fundamental physical characteristics of cottonseed oil and its derived products, i. e., viscosity, surface tension, coefficient of expansion, dielectric constant, etc., and their variation with temperature.

22. Investigations on the separation and use of phosphatides, sterols, and related products from cottonseed oil.

23. Studies on the dehydrogenation of cottonseed oil to give it drying properties, including possible addition of acetylenic compounds.

24. Investigation of the deodorization of cottonseed oil for textile finishing.

25. Fundamental investigations of the effect of metals, including flashed and heat-treatment surfaces, on the color, flavor, and stability of cottonseed oil.

26. Study of the improvement in methods of analysis of cottonseed oil.

27. Fundamental study of the pigments in cottonseed oil and the effect of processing temperatures on these substances.

28. Studies on the isolation, identification, and uses of cottonseed protein, especially for the preparation of amino acids, utilization in plastics, as a stabilizer in asphalt emulsions, orchard sprays, and other emulsions and suspensions.

29. Further studies on the chemistry and use of gossypol and of the pigments occurring in cottonseed.

30. A complete study of the relationship between morphological and histological characteristics and chemical composition.

PEANUTS

Peanuts are grown in all of the Southern States. The vines are used for forage and the nuts for animal and human food and for oil. In 1937, 2,562,000 acres of peanuts were grown, of which 1,653,000 acres were harvested for nuts. The farm value of this crop was \$41,455,000. The commercially important types are the large-podded Virginia Bunch and Runner and the small-podded Spanish peanuts.

Of the total crop of 1,321,000,000 pounds harvested for nuts in 1937, approximately 240,000,000 pounds were crushed for oil. Some of the remainder was used for seed and feed, but the bulk of the crop was used for human consumption in the form of roasted or salted nuts, as peanut butter, in candies, etc. The net domestic disappearance of peanut oil for the fiscal year ended September 30, 1937, was 114,843,000 pounds, of which 77,880,000 pounds were derived from domestic nuts. During this period net imports of the oil were 55,747,000 pounds, most of which came from the Netherlands and China. The oil belongs to the nondrying class. Approximately 90 percent of the factory consumption of peanut oil is used for the manufacture of shortening, oleomargarine, and other edible products.

As the peanut is a leguminous plant, it is potentially a soil builder. When hogging-off is practiced there is undoubtedly an increase in the nitrogen content of the soil, but when the crop is harvested for nuts and hay, soil depletion occurs.

The shelled nuts yield approximately 35 percent oil and 65 percent meal. The meal is used almost entirely as a high-protein feed for

livestock. The hulls have had some use as a mild abrasive in bur-nishing steel and tin plate, and are sometimes used as an adulterant in stock feeds. It has been demonstrated that many products can be made from peanuts. Some which have received publicity are breakfast foods, high-protein flour, vegetable milk, ice-cream powders, stock feeds in various combinations, dyes, inks, cosmetics, medicinals, etc. Nevertheless, the crop is grown almost exclusively for food or feed.

PRESENT RESEARCH

Research is being done on peanuts in a number of places, especially on breeding, as a legume in crop rotation, and on general problems; but there is need for further extensive research work. In the South, where oil has been pressed from cottonseed for more than half a century, it is natural that equipment and methods of processing and utilization developed for cottonseed are being used and adapted to peanuts and peanut oil. The increase in the amount of peanuts crushed for oil in the past 2 years, however, has focused attention on methods specifically adapted to this crop. The following research projects are in progress:

Agricultural research.

1. Genetic and agronomic investigations for the improvement of peanut varieties and their regional adaptation and place in crop rotation, especially with respect to their utilization for food, feed, and industrial purposes.

2. Studies of diseases and insect pests and methods for their control or elimination.

3. The investigation of the efficiency and nutritive value of the peanut and of peanut products as feeds for poultry and livestock, including the effects of peanuts and peanut products on the quality of pork, beef, poultry, eggs, and other products, as well as the general effect upon the health of the animals.

4. A study of possible methods of improving the flavor of peanuts and derived products.

5. Analysis of factors affecting the price of peanuts and investigation of the competition and interchangeability of other fats and oils with peanut oil.

Utilization.

6. A study of methods for improving the quality and nutritive value of margarine made from peanut oil.

7. Investigation of methods of clarification and reuse of peanut oil used in frying potato chips.

8. Utilization of peanuts and peanut byproducts, especially for the production of industrial raw materials.

9. Studies of peanuts and peanut products in relation to pellagra in certain restricted human diets.

SUGGESTED RESEARCH

Peanuts and peanut oil enjoy definite places as food products. The oil is similar in chemical characteristics to a number of extensively produced nondrying oils. It will probably not be used extensively except for food uses until more definite fundamental and technological chemical advancements are made with respect to the oil and its derived

fatty acids. Suggestions pertaining to research on peanuts and peanut products have been made as follows:

Agricultural research.

1. A greatly enlarged and more extensive and intensive breeding program, including close study of the genetics and anatomy of the plant.

2. Continuation of the agronomic investigations for the improvement of peanut varieties and their regional adaptation and place in crop rotation, especially with respect to their utilization for food, feed, and industrial purposes.

3. A study to determine the reasons for the nonadaptability of certain types of peanuts to varying conditions, paying particular attention to the relationship, if any, of photosynthesis and carbohydrate metabolism to nitrogen assimilation and to the effect of temperature, light, and moisture upon these processes.

4. Increased emphasis upon reduction of costs by improving present machinery and methods used in harvesting, stacking, curing, and handling.

5. Development of methods of lifting the whole peanut plant from the soil, drying it quickly—artificially if necessary—and grinding it into meal for stock feeding.

Processing.

6. Investigation of the effect of extraction and refining methods on quality and yield of oil.

7. Investigation of the various nonoil contaminants of peanut oil and utilization of this knowledge for improvement in methods of processing the oil.

Utilization.

8. Investigation of methods of treatment to make peanut oil suitable for use as a textile lubricant in the place of imported tea-seed and olive oils.

9. Investigation of modification of the properties of peanut oil by both physical and chemical treatments to broaden its utilization, especially in new nonfood applications.

10. Investigation of the factors which cause deterioration of peanuts and peanut oil in storage.

11. A study of the composition and the fundamental physical and chemical constants of peanut oil for the purpose of determining its value for specific uses, such as, for example, in the finishing of leathers.

12. An investigation of the suitability of the proteins of peanut meal and flour for nonfood uses, especially for the manufacture of plastics.

13. Reconsideration of the use of peanut hulls as a source of pentosans, cellulose, etc. (See *Agricultural Wastes*.)

Fundamental research.

14. Investigation of the nature and amount of sterols, phospholipids, and related substances present in peanut oil.

FLAXSEED

Flaxseed yields linseed oil, which is the principal drying oil used in the paint and varnish, linoleum and oilcloth, and printing-ink industries. Some linseed oil is used also in edible, soap, and miscellaneous

products. Flaxseed is an important cash crop in Minnesota and North Dakota, and is grown also in South Dakota, California, Montana, Kansas, and several other States. It is not a surplus crop. The peak of all-time domestic production was reached in 1924, when 31,220,000 bushels were produced with a farm value of \$68,019,000. In recent years drought and insects have reduced production drastically in the principal flaxseed-producing area. In 1934 only 5,661,000 bushels were produced with a farm value of \$9,620,000. The total net supply for domestic consumption, including imports, was 46,495,000 bushels in 1924 and 23,506,000 bushels in 1934. Domestic supply has fallen to as low as 25 percent of domestic consumption. This unavoidable decrease in domestic production has led to increased importation of foreign flaxseed and linseed oil and to the use of substitute oils. Net imports during the past 10 years have ranged from a low of about 6 million bushels in 1932 to a high of 26 million bushels in 1936.

The production of flaxseed during the decade 1927-36 averaged 13½ million bushels. The crop of 1937 amounted to 6,974,000 bushels, and that of 1938 is estimated at slightly under 8 million bushels. In recent years flaxseed has brought growers a gross income of about 8 million to 20 million dollars. The average price received by farmers has ranged from \$1.42 to \$1.90 a bushel in the last 5 years. Flaxseed is harvested in late summer, begins to move to market in volume during August, and reaches its peak movement in September and October, when 28 percent and 20 percent, respectively, is marketed on the average.

The carry-over of flaxseed during the last 3 years has been as follows:

	<i>Carry-over (1,000 bushels)</i>
July 1, 1936-----	3, 331
July 1, 1937-----	3, 339
July 1, 1938-----	2, 199

During the last century flax was considered as limited to a pioneer or new-land crop on account of its lack of resistance to the wilt disease. With the selection of wilt-resistant flaxes, its production area has been stabilized in the Northwest. There is a general desire for an increase in domestic production of linseed oil and an improvement of domestic-oil quality through plant breeding. Thus far, seed flax has been the only field crop yielding a highly unsaturated oil that has lent itself to commercial production under the American system of mechanized agriculture.

Flaxseed has been processed exclusively for linseed oil. The resulting linseed cake is used in animal feeds and is highly prized as a protein supplement. Little or no attempt has been made to use it for industrial purposes. Most of the agricultural research now being done has for its objects the breeding and selection of new varieties for high oil content in the seed, high-quality oil, disease resistance in the plant, and desirable agronomic characteristics (such as seed size, plant height, and high yielding capacity), and the determination of best cultural practices. Most of the industrial researches now being made are related to improvements in processing linseed oil for use in the formulation of protective coatings.

PRESENT RESEARCH

For the purposes of the survey the present research falls largely into the following groups: Agricultural research; processing; utilization; and fundamental research in chemistry, physics, and technology.

The agricultural investigations have been made in the State agricultural experiment stations and the United States Department of Agriculture, while most of the technological developments have come from industrial laboratories.

Agricultural research.

1. Genetic studies for the purpose of determining the mode of inheritance of seed size, seed color, oil content of seed, oil quality, and other plant characters associated with the economic demands of flaxseed.

2. The breeding of flax for improved yield, quality, and adaptation, including resistance to disease, pests, and adverse production conditions.

3. Investigation of the characteristics, structure, classification, and distribution of flax types and varieties.

4. Agronomic studies which have for their purpose the determination of the effects of variety, climate, soil, fertilization, crop rotation, date of seeding, and the time and method of harvesting on the adaptation, yield, and size of seed and on the content and quality of oil and meal.

5. The study of flax diseases and insect pests and their control.

6. Investigation of the rate of deposition of oil and the occurrence of desaturation of the oil in flaxseed during maturation.

7. A study of the quantity, composition, and characteristics of the oils produced in flaxseed grown under definite and controlled environmental conditions (water cultures).

8. Development of rapid and reliable methods for determining the commercial value of flaxseed, i. e., the quantity and quality of oil that can be obtained.

9. Study of the relationship of grade to intrinsic value of flaxseed, in order to determine the advisability of using oil content and iodine number as additional or supplemental factors for grading purposes.

10. Investigation of the factors of dockage and foreign material in the application of the official grain standards for flaxseed.

11. Analysis of factors affecting prices of flaxseed, including competition and interchangeability of other fats and oils with linseed oil.

12. Survey of commercial production in various localities with respect to oil content of seed, iodine number of oil, yield, and certain climatic factors for the purpose of determining the limits of economic production in the principal producing area.

Processing.

13. Investigation of the methods and economics of processing flaxseed for the recovery of oil and of the effect of processing methods on the quality of the oil and meal produced.

Utilization.

14. Investigation of the methods and economics of refining and bleaching linseed oil and of treating the raw oil for producing boiled, blown, bodied, stand, "top-fired," and other specially processed linseed oils for the many purposes for which they are used.

15. Utilization of linseed oils, alone and blended with other oils, in the formulation of protective coatings, linoleum, oilcloth, and printing inks.

16. Investigation on the chemical mechanism of and the effect of processing on the yellowing of linseed oil in paint, varnish, and enamel films, and methods for checking or inhibiting yellowing.

17. Study of linseed oil films: (1) Effect on the film character of bodying and types and proportions of dryers; (2) drying properties and stability of films under accelerated weathering conditions; (3) rate of oxygen absorption and rate of decomposition of oxidized and polymerized films; (4) the mechanism of drying, peroxide effect, carbonyl content, change in iodine number, and effects of pro- and anti-oxidants on drying and decomposition rates; (5) the fortification of the oil with natural and synthetic resins.

18. The processing or technical alteration of linseed oil so that it may compare with and be substituted for tung oil in fast-drying and water-resisting varnishes and enamels.

Fundamental research in chemistry, physics, and technology.

19. Development of improved and new methods for testing and evaluating drying oils and protective coatings containing them.

20. Comparison of the properties of synthetic glycerides with those of glycerides derived from natural oils.

21. Investigation of the chemistry of unsaturated fatty acids and their identification and quantitative determination by chemical and spectroscopic methods.

22. Study of interfacial tension between pigments and oils, including development of methods for measuring this property.

SUGGESTED RESEARCH

Flax has been considered a relatively temporary pioneer or new-land crop and consequently research relative to its production has been inadequately supported. Investigation of the fundamental chemistry of the oil and meal also has lagged. With adequate research increased production and extended uses, especially for specific purposes, should be forthcoming.

Agricultural research.

1. Intensification of the genetic studies and breeding of flax for the development of new varieties having such desirable characteristics as disease resistance, high yield, high oil content and oil quality of seed, and adaptation of wider ranges of production. Success of these investigations would do much toward increasing production and improving the quality of the domestic linseed-oil supply.

2. A detailed investigation of the chemical composition and the physiology of the flax plant for the purpose of determining the fertility requirements and the factors contributing to disease resistance and to the formation of highly unsaturated oil in the seed.

Processing.

3. Further fundamental studies of the recovery of linseed oil from flaxseed by press, expeller, and extraction methods, including a study of the economics of production and the quality of the oil and meal.

Utilization.

4. Further investigation of the chemical mechanism of the yellowing of linseed-oil film and means for its prevention.

5. A further study of the chemistry and physics of the linseed-oil film during and after drying, for the purpose of determining the relative value of different driers and the effect of oil processing and the constituent fatty acids on the rate of drying, gaseous products developed, yellowing, durability, and water resistance of the film.

6. Investigation of the production of short-chain fatty acids and other derivatives from linseed-oil fatty acids and the possibility of using linseed-oil fatty acids as industrial raw materials.

7. Determination of the nature of the nonglyceride substances, such as unsaponifiable matter, phospholipids, and sterols, in linseed oil and the development of new uses for these products.

8. Development of new uses for linseed oil, linseed-oil fatty acids, and their derivatives as textile lubricants, detergents, and other industrial products.

9. Development of processes for the treatment or formulation of linseed oil to replace tung oil in varnishes and enamels.

10. An exhaustive investigation of the proteins and mucilaginous substances in linseed meal with the object of developing new industrial uses for them.

Fundamental research in chemistry, physics, and technology.

11. Investigations of laboratory and industrial methods for separation of the individual fatty acids of linseed oil and recombining them with glycerol to produce synthetic oils of superior drying properties.

12. Extension of the investigations on the structure, identification, and estimation of fatty acids of linseed oil by chemical and spectroscopic means.

13. Investigation of the fundamental chemical and physical properties of raw and processed or treated linseed oil, such as surface tension, viscosity, coefficient of expansion, etc.

14. Intensification of the studies dealing with the measurement of interfacial tension between drying oils and pigments. Interfacial tension is important in relation to the wetting of pigments in the manufacture of paints and enamels.

15. The development of more informative methods of evaluating oils with respect to their composition and adaptability.

16. Study of the relationship of iodine number to the content of oleic, linoleic, and linolenic acids in the glycerides of linseed oil. It is theoretically possible for oils of identical iodine number to have radically different compositions and hence different drying properties.

SOYBEANS

Cultivation of soybeans as a soil-improvement, hay, or cash seed crop has become increasingly important to American agriculture, especially during the last 10 years. Production of beans for seed and crushing increased from about 2,283,000 bushels in 1917 to 45,272,000 bushels in 1937, and 57,665,000 bushels in 1938. In 1917 less than 500,000 acres were devoted to the growing of soybeans for all purposes. In 1937 the number of acres of soybeans grown was 7,005,000, of which 2,549,000 acres were harvested for beans. In 1938 the total

acreage was 7,789,000, of which 2,898,000 acres were harvested for beans.

Despite this increase in production, the farmer has experienced little difficulty in disposing of his crop and industry has at the same time been able to find outlets for the products and byproducts derived in processing the seed. However, the price obtained by the farmer for his beans and that received by the processor for the derived products has varied considerably from year to year. The fluctuation in prices has been partially influenced by factors other than those which can be entirely related to the costs of production and processing, or to the relative production of beans and competing sources of oil or of meal and oil.

Part of this variation in price doubtless can be attributed to difficulties in adapting the derived products to specific uses, industrial as well as food and feed. These difficulties merely reflect a lack of fundamental knowledge concerning the chemical, physical, physiological, and nutritional properties of products derivable from the beans, as well as a similar lack of knowledge concerning the agronomic and genetic characters of the plant; and to a lesser extent the best methods of harvesting, storing, and processing the seed.

The products derived from soybeans consist principally of meal and oil, from the latter of which may be derived minor products, such as phosphatides and sterols. The beans also contain 10 to 15 percent of crystallizable sugars which together with the cellulose are usually to be found in the meal.

At present the bulk of the meal is fed to livestock while minor amounts are consumed as human food in a wide variety of products, such as bakery goods, candy, diabetic foods, meat sauce, beer, noodles, sausage filler, etc. Only very small amounts of the meal or derived protein is used industrially as sizing for paper and textiles, adhesives, plastics, foundry cores, etc. On the other hand, the bulk of the oil is hydrogenated for the production of vegetable shortening and oleomargarine, or refined for use as a salad oil. Approximately 10 percent of the oil finds its way into the drying-oil industry for use in the preparation of paints, varnishes, synthetic resins, printing inks, linoleums, and oilcloth, and a still smaller percentage is consumed in the production of detergents, lubricating greases, core binders, etc.

PRESENT RESEARCH

Considerable research is being conducted at the present time in an effort to solve many of the difficulties attending the introduction of a relatively new crop and new products into American agriculture and industry.

The processing of soybeans is principally carried out by two methods, namely, pressing and solvent extraction. In either case the beans are cracked, flaked, and conditioned with respect to moisture and temperature prior to the separation of the oil. The meal produced by either of these processes may be used directly as feed for livestock or processed further by heat or other treatment to increase its digestibility. The oil is usually clarified by settling or centrifuging and may or may not be further refined, bleached, and deodorized prior to its entrance into industrial channels.

Research work on the utilization of the products derived from soybeans naturally falls into two classes, namely, that pertaining to the oil and that pertaining to the meal or protein. Furthermore, the research on the oil can be subdivided into studies pertaining to its use in (a) drying-oil industry, (b) edible-oil industry, (c) inedible-oil industry.

The following description of this research is subdivided into several categories.

Agricultural research.

1. Genetic studies, particularly with reference to the effect of selection and hybridization on the chemical composition and the forage, feed, food, and industrial uses of soybeans and derived products.

2. Investigations of the effect of date of planting, method of seeding, rate of seeding, soil and fertilizer treatment, environmental factors and stage of maturity on yield, and chemical composition of soybeans.

3. Investigations of the relations of color of seedcoat and effect of seedcoat injury on the germination, growth, storage, and composition of beans.

4. Investigation of the chemical composition and industrial uses of different varieties of soybeans and their derived products; also the extraction of phospholipides from the oil.

5. Analysis of soybeans to determine the variation in chemical composition resulting from differences in variety, soil type, fertilizer treatment, and other cultural conditions.

6. Studies of the type of equipment and methods of harvesting on the yield, quality, and composition of soybeans.

7. Investigation of the relative values of soybeans for forage, commercial seed, and vegetable purposes; also the food quality of such products as soybean milk, milk curd, and milk residue.

8. Studies on the respiration of soybeans, and the effect of storage methods and environment on the germination, composition, and chemical and physical properties of the beans and their derived products.

9. Study of the quantity and quality of oil and protein in soybeans in relation to grading factors defined in the U. S. Standards.

10. Analysis of the factors affecting prices of soybeans, and the investigation of the competition and interchangeability of other fats and oils with soybean oil.

Processing.

11. Studies on the variation in the release of oil by different varieties of soybeans and by the use of different solvents; also similar studies with respect to the water-soluble protein.

12. Studies of the design, specification, and installation of semi-plant scale equipment for both the expeller- and solvent-extraction methods.

13. Processing of beans under controlled conditions to provide standardized products for further research.

14. Investigation of the effect of various solvents and conditions of operation on the yield and quality of meal and oil for special industrial applications.

15. Heat treatment of solvent extracted meal to improve its digestibility as a livestock feed.

16. Investigations of the effects of variations in processing (including refining, bleaching, and deodorizing) on the physical and chemical properties of soybean oil, especially color and odor.

Utilization of oil.

17. Investigation of methods of improving the drying property of soybean oil by chemical and physical methods, including treatment with oxidizing agents, acylation, use of catalysts, heat bodying, etc.

18. Studies of the drying rate and durability of resultant films of mixtures of soybean oil with tung, perilla, linseed, oiticica, hempseed, and similar oils, before and after high-temperature treatments for short periods. Investigation in this field has led to date to the production of commercial paints containing up to 35 percent soybean oil, especially red barn paints with soybean and perilla oil, roof and freight-car paints with soybean-hempseed oils, and some aluminum paint for interior and exterior use. A considerable amount of this oil is also used in oil mixtures for the preparation of so-called second-line house paints.

19. Studies on the formulation, drying rate, gloss retention, water resistance, durability, and related properties of paints, varnishes, and interior enamels produced with soybean oil and with mixtures of soybean and other more rapid drying oils.

20. Investigation of the production, properties, and uses of synthetic resins derived from soybean oil and from soybean oil fatty acids.

21. Studies of the use of soybean oil as a core-binding material for use in foundry work.

22. Investigation of the effects of temperature, pressure, and catalysts in the selective hydrogenation of soybean oil and their relation to the stability of the finished product.

23. Studies in the sulfation and phosphorization of soybean oil for use as a fat-liquoring oil and as a driving oil for the soaking of silk in the place of imported olive oil. Work thus far has been confined to a study of the degree of sulfation and methods of neutralizing and washing the oil after treatment with sulfuric acid.

24. Investigation of the use of soybean oil in soft soaps and special detergent agents.

25. Separation of phosphatides and sterols from crude soybean oil by various methods and studies on the uses of crude and semipurified phosphatides as fat stabilizers, emulsifying agents, etc.

26. Studies on the effect of soybean oil in admixtures of bituminous materials and as primers to improve the surface properties of hydrophilic stones to prevent stripping of asphalt in pavements.

Utilization of protein.

27. Investigation of methods for the production of purified proteins from soybean meal and a study of their physical and chemical properties.

28. Laboratory and semiplant scale studies of methods of extracting various proteins and protein fractions, together with practical studies of the application of these products to the production of (a) adhesives for use in the manufacture of briquets, (b) glues for fabricating plywood and laminated papers, (c) modified resin sizes for wall paper and other papers, (d) binder for china clay in the coating of high-gloss

book, magazine, and label papers, (e) cold-water paints, (f) retarder for gypsum plasters, and many other products.

29. Investigation of methods and materials for the production of plastics from soybean meal and protein, especially in combination with phenol-formaldehyde, urea-formaldehyde, and other resins. Also studies on plasticizing and waterproofing agents for use in soybean plastics.

30. Investigation of the production of uniform and ash-free fractions of soybean protein for use in the production of synthetic fibers. Studies of the effect of variation of viscosity, H-ion concentration, and aging of protein solutions in fiber-spinning operations.

31. Studies on the production of soybean meal and protein for use as a foam stabilizing agent for beer, creaming agent for candy, adjunct in the production of brown or golden color in bakery products, pre-cooked cereals, and dog food.

Fundamental research.

32. Studies on the fundamental composition of soybean proteins, including investigation of the carbon, hydrogen, nitrogen, sulfur, and oxygen ratios as well as the constituent amino acids comprising the protein molecule and their relation to its spinning properties.

33. Investigation of the chemical composition of the glycerides and derived fatty acids of soybean oil especially by means of molecular distillation, solvent fractionation, and the distillation of esters and free acids.

34. Studies on the isolation and characterization of soybean carbohydrates with particular reference to sucrose and stachyose.

35. Investigations of the enzyme systems of soybeans, particularly with reference to the isolation, identification, and industrial application of amylase.

36. Investigation of existing methods and development of new methods and techniques for the analysis of soybeans and their derived products.

SUGGESTED RESEARCH

It would appear from the number and type of the current research projects which are described above that the soybean is being extensively investigated from many angles. This fact is apparently true so far as agronomic, genetic, and other agricultural phases of research are concerned. Further evidence on this point is to be found in the fact that few suggestions for projects of importance in the field of agricultural research were submitted during the course of the survey of the various industries, State experiment stations, and land-grant colleges.

On the other hand, the number and variety of suggested research projects pertaining to the processing and utilization of soybeans suggest that much more information is needed in order to make the best use of this agricultural crop. Experience to date clearly demonstrates that it is possible, on the basis of a broader fundamental knowledge of the composition, nutritive value, and chemical and physical properties of the soybean and its derived products, to adapt it to a wide variety of new uses. The following suggested research, which is not at present in progress, or is at best only inadequately prosecuted, is indicative of the type of information which is needed in order to extend and broaden the uses for these commodities.

Utilization for food, beverages, and medicines.

1. Study of vegetable varieties of soybeans most suitable for canning.
2. Investigation of means of using edible soybeans in southern diets.
3. Studies on better methods of debittering soybeans intended for food and feed uses.
4. Removal of the odor of soybean flour intended for use as a foam-producing agent, including a study of the differences in expeller, nonalcohol-solvent extracted, and alcohol-solvent extracted meals for use as a foaming agent in beer.
5. Development of a less hygroscopic flour for use in cookies.
6. Preparation of special carbohydrates for pharmaceutical use.
7. Further studies on the shipping and creaming properties of soybean protein for use in cream fillings in confectionery.
8. Investigation of methods for the detection of soybean meal or protein which has been incorporated in various food products.

Utilization of meal for industrial products.

9. Preparation of proteins and protein solutions of uniform quality for use in the production of adhesives, and for use in spinning fibers.
10. Study of the physical and chemical properties of soybean protein which are responsible for its adhesive quality.
11. Study of methods to improve the solubility of soybean protein in alcohol which is essential to its use in certain manufacturing operations.
12. Investigation of the use of soybean meal and protein for filling and finishing leather, compounding with rubber, and for the production of size for cotton cloth and paper.
13. Further studies on the production of plastics, including a study of plasticizing and waterproofing agents, for specific uses such as molded shoe heels.
14. Study of the use of resins and soybean plastics in permanent book paper in place of alum sizing.

Utilization of oil for industrial products.

15. Investigation of the mechanism of polymerization and drying, especially a study of the phenomenon of surface drying of soybean oil as contrasted with the body drying of linseed oil.
16. Investigation of the reactivity of soybean oil with synthetic resins, particularly maleic and similarly reactive resins, and the application of these resins to the production of enamel oils.
17. Development of soybean-oil varnishes for paper coatings, laminated papers, impregnation of electrical coils, and core windings.
18. Development of oils and fat liquors from soybeans for use in the leather industry, especially with reference to use of soybean lecithin in fat-liquoring leather.
19. Further studies on heat bodying, blending, resin fortification, drier combinations, and pigmentation of soybean oil for use in the preparation of paints, varnishes, and enamels.
20. Further studies on the mechanism of stability and reversion and the development of methods for determining the oxidative and photo-chemical instability of soybean oil intended for use in shortening and oleomargarine.
21. Development of new uses for lecithin and improved and cheaper methods of isolating and purifying lecithin and sterols from soybean oil.

22. Further studies on the application of soybean oil to the production of printing inks, linoleum, oilcloth, cutting oils, impregnation of electrical coils, core oils, etc.

23. Use of soybean oil in brake fluids and in graphite-oil mixtures for dry lubricants for coating shells in storage. The coating must not crack during storage, and must not subsequently gum the gun during firing.

CASTOR BEANS

A considerable quantity of castor oil is used in this country in a wide variety of products, including soaps, paints, varnishes, linoleum, oilcloth, printing inks, hydraulic-brake fluids, shock absorbers, medicinals, and lubricants, and in the form of sulfonated oil, under the name "Turkey red oil," for use in dyeing cotton fabrics.

In the last quarter of the nineteenth century considerable quantities of castor beans were grown in Kansas, Oklahoma, and other mid-western States. The maximum production in Kansas occurred in 1879, when 68,170 acres produced 766,143 bushels of castor beans valued at \$1 a bushel. During the period 1876 to 1916 the returns to Kansas growers ranged from \$0.83 to \$1.72 a bushel. Production of this crop constantly declined and almost disappeared from American agriculture during the first decade of the present century. As a result of the demand during the World War for castor oil as an aircraft lubricant several thousand tons of seed were produced in the Southern States, but since then and until very recently little effort has been made to reestablish this crop on a sound agricultural and economic basis.

Practically the entire production of castor oil is derived from imported beans. In 1936, 164 million pounds of castor beans were imported and in 1937, 147 million pounds. Thirty-two million pounds of castor oil were consumed domestically in 1936 and 35 million pounds in 1937.

With the discovery by Scheiber in Germany of a practical method for the treatment of ricinoleic acid whereby a molecule of water is removed with the formation of an additional double bond, it had become possible to convert castor oil into a new product having wide application in the drying-oil field. The properties of this synthetic drying oil permit its use as a substitute for linseed and tung oils, although chemically and physically it is identical with neither of them. Several of these castor-oil dehydration processes are now being operated in the United States for the production of a synthetic drying oil, and the consumption of this "synourine oil" has risen from 2 million pounds in 1933 to 8 million pounds in 1937. The consumption of synthetic drying oil made by the dehydration of castor oil will no doubt become increasingly important in the future.

The development of other new uses for castor oil and the search for crops adapted to marginal lands and as replacement crops for commodities that are annually overproduced, as well as the successful industrial dehydration of the oil, have stimulated considerable activity in the reintroduction of this crop in the United States. However, before the production of castor beans can be undertaken successfully in this country considerable research will be required to determine the varieties, soil, and climatic conditions, and harvesting and handling methods best suited to their cultivation here. Some

work along these lines has already been started, as is evidenced by present research.

PRESENT RESEARCH

The research now under way on castor beans is principally concerned with castor oil, but there is some activity in the field of utilization of the press cake and stalks and other parts of the plant.

The press cake, derived from expressing the oil from the castor bean, contains the agglutinating protein and ricin. The latter is toxic to many animal organisms and therefore must be removed before the cake can be used industrially. Methods have been developed in Germany for removing or inactivating the toxic principle.

The following research is being conducted:

Agricultural research.

1. Investigation of the effect of environment on the oil content of the castor bean.
2. Study of varieties best adapted for oil production, their composition, soil adaptation, and proper cultural methods.
3. Development of machinery for harvesting.

Processing.

4. Improvement in the methods of processing castor oil, including studies on refining methods, refining losses, color, odor, etc.
5. Studies on improved methods and on catalysts for the dehydration of castor oil.

Utilization.

6. Studies of the use of sulfonated castor oil in sprays and as a base for cutting oils.
7. Production of isobutyl undecylenamide from cracked castor oil for use as a fly spray.
8. Production of dibutyl sebacate for use as a bonding agent in the production of shatterproof glass.
9. Investigation of dehydrated castor oil for the production of paints and varnishes, especially on the basis of its own properties rather than as a substitute for tung and linseed oils.
10. Development from castor oil of more suitable products for use in finishing and dyeing textile fibers.
11. Use of dehydrated castor oil and its distilled fatty acids in the production of modified alkyd resins.
12. Greater use of castor oil and its derivatives as emulsifying agents for specific uses.
13. Study of methods of heat and other treatments for the production of mineral-oil soluble products for use in special lubricants.
14. Application of castor oil to the retting of hemp.
15. Attempts to find industrial outlets for the press cake, which is now used principally as a manure.
16. Investigation of ricin as an insecticide. It has been observed that certain insects, notably the Japanese beetle, die after ingesting the leaves of the castor plant. However, the plant is known to be host to insects of several natural orders and there are reliable reports of fields of castor beans in Florida being completely denuded by the army worm. The plant is also host to more than a hundred bacterial and fungus diseases.

17. Investigation of castor stalk as a source of cellulose for use in the viscose and paper industries. (See also Fiber Crops.)
18. Studies of other industrial uses of parts of the plant.

SUGGESTED RESEARCH

As previously stated, it is essential to the successful introduction of the castor plant as a cash farm crop that its cultural aspects be given prime consideration, and it is consequently not surprising that a considerable number of agricultural projects have been suggested for investigation. These suggestions are contained in the following list of projects:

Agricultural research.

1. Investigation of known as well as new varieties of castor beans with respect to the content of oil and possible reduction in the ricin content of the plant.
2. Genetic studies to develop indehiscent strains or varieties, or at least to minimize the dehiscence of the castor-seed pod. Since the castor pod is extremely dehiscent and tends to eject its seed on ripening, thus constituting a serious handicap to mechanical harvesting, such studies are urgently needed.
3. Studies directed toward breeding mold-resistant varieties and strains, since castor beans have a tendency to mold readily.
4. Agronomic studies on castor beans for areas other than Texas, Oklahoma, Kansas, Nebraska, Arkansas, and Missouri, especially in the South, the Virgin Islands, and California.
5. Development of machinery adapted to the harvesting and handling of castor beans.
6. Investigations of the economics of production, harvesting, and handling of castor beans, together with a study of methods for financing these operations.

Utilization.

7. Fundamental studies on the sulfonation, dehydration, controlled hydrogenation, heat treatment, and other chemical and physical reactions of castor oil and derived acids.
8. Investigation of best methods of utilizing dehydrated castor oil in paints, varnishes, and enamels, especially by blending with other oils and by means of heat treatment.
9. Studies on the proper drier combinations and a study of the film-forming properties of dehydrated castor oils, especially color, wetting properties, wrinkling, etc.
10. Investigation of the chemical reactions of dehydrated castor oil with other substances, such as maleic, phthalic, adipic, and other anhydrides, which may lead to the formation of synthetic resins.
11. Studies on the cracking and destructive distillation of castor oil, especially distillation with reference to effect of variables on the type and yield of products, such as undecylic, sebacic, and similar acids, heptaldehyde, and related products, and the application of these products in various processes.
12. Studies on the use of press cake, leaves, stems, etc., with the view of developing new insecticides and fungicides.

TUNG NUTS

Tung oil is obtained from the nuts of the tung or China wood oil tree. The oil ranks second in importance in the drying-oil industry, and is used extensively in the manufacture of varnishes and enamels. The water-resisting properties it imparts to the dried varnish and enamel films is attributed to elaeostearic acid in the oil. Tung is the only oil of commercial importance that contains this particular conjugated unsaturated fatty acid.

The United States is dependent on the Orient for its supply of tung oil. The importations in 1937 were about 175,000,000 pounds. The apparent disappearance in the same year was about 155,000,000 pounds, of which about 85 percent was used in the paint and varnish industries and the rest in the manufacture of linoleum, printing inks, and miscellaneous products. Tung oil represented about 18 percent of the oils used in the drying-oil industries in 1937.

Tung nuts were first planted in the United States between 1900 and 1905. One of the earliest successful small planting was made at Gainesville, Fla. Since about 1923, commercial plantings have gradually increased and at the present time there are probably over 150,000 acres under cultivation. The yield of nuts for the year 1938 has been estimated at 20,000,000 pounds and the oil at 4,000,000 pounds. Mississippi now has the most extensive plantings, but Florida, Louisiana, Alabama, and Georgia are also important producers of tung nuts. Due to the susceptibility of the tung tree to frost and other adverse climatic conditions, the yield of nuts has been very variable and in some years the crop has been a complete failure.

The kernels of the tung nut contain about 50 percent of oil. The meal or cake after the recovery of the oil, owing to its strong purgative properties, is unsuitable for feeding stock and is chiefly used as a fertilizer. Some meal has been used in making lampblack.

Tung oil is the principal paint and varnish oil of China, where it is also used in the manufacture of oil lacquer and soap, and as a water-proofing agent for paper and fabrics. When burned with insufficient air, the oil yields the carbon which the Chinese use in making india ink.

Elaeostearates of cobalt, lead, manganese, and zinc, which are important ingredients of paint and varnish driers, and aluminum elaeostearate, which is employed as a waterproofing material for masonry, are made in considerable quantities from the fatty acid of tung oil.

Since the foreign supply of tung oil is subject to sharp fluctuations in price, there is considerable industrial interest in a domestic source of tung oil and in the development of other processed domestic oils which can be substituted for this oil. Recently the United States Department of Agriculture has undertaken extensive investigations of tung-nut production, supplementing the work of the State agricultural experiment stations.

PRESENT RESEARCH

The following are the agricultural investigations pertaining to the domestic tung-oil industry which are now being carried out, or will be started soon:

Agricultural research.

1. A study of the relationship of soil characteristics, especially acidity, aeration, drainage, and mineral content, to tung-tree growth and fruit production.

2. A study of the nutritional requirements of tung trees, with regard to fertilizers (kind, quantity, and time of application), soil amendments, and minor mineral elements.

3. Investigations on the cultural requirements of tung trees, including studies on the relative values of mulching, sod or other permanent cover, and annual cover crops, and on the effects of type, depth, and frequency of cultivation on the soil and on tung-tree performance.

4. Studies to determine the pruning and training methods which will insure maximum production at the least cost.

5. A study of the pollination of tung flowers to determine the agencies of pollination, viability of pollen, and the extent and relative value of self- and cross-pollination.

6. Studies on the variability of tung trees, with regard to cold resistance, fruiting, performance, and oil content of their nuts, in the seedling orchards already established.

7. Studies to determine how tung-tree orchards should be managed to insure maximum and economical production and to locate outstanding trees which could be used for multiplication as varieties or as parents in breeding experiments.

8. Development of improved methods of propagation by budding and grafting to provide for rapid multiplication of the trees of standard varieties at low costs.

9. Application of approved methods of selection and hybridization to find or create promising seedlings to be tested in several localities and under different conditions to determine their adaptability, productivity, and general suitability as standard varieties for planting in commercial orchards.

10. Studies of methods of harvesting, curing, and storing tung nuts in order to determine those most satisfactory and economical for handling the crop.

11. Investigation of the importance, specific causes, and nature of diseases and the development of economical control measures. Already a number of diseases are known to attack the wood, foliage, or fruit of tung trees.

12. Investigations to determine the nature and extent of the influence of cultural and other factors upon the quantity and the physical and chemical characteristics of the oil in tung nuts.

13. Investigation of the nonoil constituents in tung oil produced under different cultural conditions in order to ascertain their effect upon drying quality of the oil.

Processing.

14. Investigation of the efficiency of expression and solvent methods for the recovery of tung oil from domestically produced nuts.

Utilization.

15. Technological research on the utilization of tung oil in surface coatings, particularly the formulation of varnishes, enamels, and oil lacquers having desirable properties, such as rapid drying, resistance to light and water, durability, and flexibility.

16. Development of improved methods for the storage of tung fruits and nuts in order to prevent or minimize deterioration of the oil.

17. Study of the proteins and other organic substances in tung-oil press cake for the purpose of developing more profitable methods of utilization.

18. A basic study of the chemical and physical properties of elaeostearic acid from tung oil, including its reaction with maleic anhydride, with regard to possible uses.

SUGGESTED RESEARCH

Since the problems of domestic tung-nut production have been surveyed recently, and new and enlarged investigations organized and instituted, few new suggestions for research on this crop have been offered. The few projects which have been suggested are as follows:

Agricultural research.

1. Investigations on the control of insects and fungi which attack tung trees.

Utilization.

2. Broadening of the fundamental investigations on the chemical and physical properties of elaeostearic acid.

3. Extension of studies on the isolation of elaeostearic acid and determination of its function in condensation and polymerization reactions, particularly with other reactive molecules such as phthalic anhydride.

4. Intensification of the investigation on proteins and other organic substances in the meal or press cake especially as possible raw materials for industrial utilization.

CORN- AND WHEAT-GERM OILS

Germ oils are those oils which can be expressed or extracted from the germ of cereal grains such as corn, wheat, barley, oats, and rye. The commercial production at present is confined primarily to corn oil as a byproduct of the starch and certain fermentation industries. Minor quantities of wheat-germ oil appear on the market from time to time. Little or none of any of the others is produced commercially. Related to germ-oil production is the recovery of the oils derivable from bran, hulls, and rice polishings, but these are not at present commercial products in this country.

Because of their chemical characteristics and stability, the germ oils are used largely for food. The factory consumption in 1937 was 83,812,000 pounds, of which 63,883,000 pounds were used for miscellaneous edible products, mainly salad oil. The apparent disappearance of corn oil in 1937 was 166,000,000 pounds, the largest amount on record. This was, however, only 1.8 percent of the total disappearance of all fats and oils, and less than 10 percent of the apparent disappearance of cottonseed oil in the United States in the same year.

The germ oils have been investigated from time to time and substantial information is available concerning their general composition and nature. Wheat-germ oil differs from other germ oils in having some 10 percent of linolenic acid compared to little or none for the other germ oils. About 20 years ago an attempt was made to isolate

and identify the various sterols present in germ oils, but this work should now be repeated. The knowledge of sterols has been completely revolutionized since that time. The chemical constitution of not a single sterol was then known, whereas today not only are their constitutions quite accurately known, but some of these sterols can be and are being used as raw materials for the synthesis of more valuable products, such as the sex hormones.

PRESENT RESEARCH

The following research projects applying to germ oils are being investigated:

1. Some work on the concentration and isolation of sterols, vitamins, and other physiologically active substances from germ oils.
2. Limited studies on the isolation and concentration of antioxidants from germ oils.
3. Preliminary studies of the odorous constituents of germ oils, with special reference to corn oil.
4. Tests of corn oil for its value as a component of insecticidal sprays.

SUGGESTED RESEARCH

Suggestions for research on germ oils received during the course of the survey deal mainly with biochemistry or with problems arising as a result of processing. They may be listed as follows:

1. Isolation and identification of the physiologically active substances, especially vitamins and related products present in germ oils.
2. Isolation and identification of the plant pigments and odorous constituents present in germ oils.
3. Isolation and identification of the constituents of the unsaponifiable fraction of germ oils, especially the sterols and antioxidants known to be present.
4. Study of the variations in the germ oils derived from white and yellow corn.
5. Study of the differences in yield and type of germ oils produced by dry and wet milling of grain.
6. Investigation of differences between expelled and extracted germ oils, especially those from corn and wheat.
7. Study of expeller process oil to determine what effects the processing has on the quality of the oil and meal.
8. Analysis of factors affecting prices of corn oil and investigation of the competition and interchangeability of other fats and oils with corn oil.
9. Study of corn oil as a possible substitute for coconut oil, especially in the manufacture of white leather.
10. Investigations of corn-oil sludge, which is now used only by soap manufacturers, to determine the identity and nature of the substances present and possible development of industrial uses for these materials.
11. Studies to determine what differences exist in the corn-oil sludges produced by the dry and the wet processes of milling.

MISCELLANEOUS OIL SEEDS

A number of oils which for the most part are imported for domestic consumption may be treated as a miscellaneous group. These oils, with the exception of olive oil, have been used in the main as substitute oils. Sesame oil, however, has a specific use in prepared flour mixtures because of its chemical stability with respect to rancidity, and rapeseed oil is used as a lubricant. A desire has been expressed for a domestic supply of hemp, sunflower, safflower, rape, chia, perilla, lallemantia, jojoba, and sesame oils.

Babassu oil.—Babassu oil, obtained from the seed kernel of a palm abundant in some parts of Brazil, is a nondrying edible oil of recently acquired importance in international trade. The domestic factory consumption of this oil in 1937 was 42 million pounds, of which about two-thirds was used in the manufacture of edible products and the rest for soap making.

Chia oil.—Chia oil is obtained from the seed of *Salvia hispanica*, a plant native to Mexico, where the seeds are chiefly used for the preparation of a beverage. This plant belongs to the mint family and grows to a height of 5 or 6 feet. Chia oil is a drying oil which resembles linseed and perilla oils in type and percentages of unsaturated fatty acids. Recently some interest has been aroused in the possibility of its domestic production for use in the drying-oil industry. Although some study has been given the plant as a domestic crop, it is essential to explore fully such factors as its soil, fertilizer, and climatic requirements; possibility of improvement through plant breeding and selection, cultural practices, harvesting, handling, and marketing methods; and many other factors before large-scale plantings are attempted.

Hempseed oil.—Hempseed oil is similar to linseed oil in type and percentage of unsaturated fatty acids and is considered an excellent drying oil. At times, depending on market prices and import duties, both the seed and oil have been imported from Europe and the Orient. Hempseed imports averaged about 29 million pounds annually for the 5-year period 1931–35 and rose to 63 million pounds in 1936. The oil equivalent of the imported seed amounted to 7 and 15 million pounds, respectively, for the same periods. With the recent shortage of domestic drying oils there is some interest in hemp culture as a source of drying oil. This plant, however, is the source of the drug marihuana and there are certain restrictions on its culture and handling. Furthermore, public opinion on the marihuana question has been aroused to such an extent that the extension of the hemp acreage over that at present grown for the fiber crop may meet with general public disapproval.

Jojoba oil.—Jojoba oil is not at present available in commercial quantities. It is derived from the seeds of a shrub, *Simmondsia californica*, which grows wild in the arid regions of Arizona, California, and western Mexico. The jojoba plant is adaptable to cultivation on marginal lands. In the wild state the plant produces 150 to 200 pounds of seed per acre. The seeds yield 40 percent of oil.

On the basis of its chemical constitution, which is similar to that of sperm oil, the product derived from the seeds would be classified as a true wax. However, because both the acids and alcohols of which it is made up contain 20 or 22 carbon atoms in their chains and are unsaturated, it is a liquid, and it is therefore considered advisable to

call it a nonfatty oil and to classify it with the seed oils. Because of its unique chemical characteristics it has many interesting possibilities, none of which has been properly explored, principally because of the difficulty of obtaining supplies of the material.

Lallemantia oil.—*Lallemantia* oil is obtained from the seed of *Lallemantia iberica*, which belongs to the mint family. The plant is cultivated in Russia for its oil, which is similar to linseed oil, has very fine drying properties, and may find application in paints and varnishes. This oil has never been an item in international commerce.

Oiticica oil.—*Oiticica* oil is found in the seeds of a large tree of the family Rosaceae which is native to northeastern Brazil. It contains licanic acid, which is similar to the elaeostearic acid found in tung oil. This oil is one of the most recent additions to the supplies of commercial drying oils. Imports were first reported in 1936, and in 1937 amounted to a little more than 3½ million pounds. The potential supply of the oil in Brazil is reported to be very large. Although considerable experience has been gained during the past year in its use as a substitute for tung oil, it has not been freely accepted for this purpose. The technical utilization of this oil is, however, being further investigated.

Olive oil.—Olive oil, obtained from the fruit of the olive tree, has been and is the primary and historical edible oil of the Mediterranean peoples. The average annual world production is approximately 2 billion pounds. Domestic production of olive oil is practically limited to California and has never exceeded 7 percent of domestic consumption in the years for which it has been reported. Olive oil is refined and used directly for food purposes. Limited amounts, apparently inedible, are used for making soap, as a textile lubricant, and for other miscellaneous purposes. The principal adulterants are tea-seed oil and rapeseed oil.

Perilla oil.—In recent years considerable quantities of perilla oil have been imported from the Orient, largely from Japan and Kwantung Province in China, where the seed is crushed and pressed and the cake used as a nitrogenous fertilizer. Importations increased from 7 million pounds in 1926 to 118 million pounds in 1936. Increased import duties have since reduced importation.

Perilla is a drying oil resembling linseed oil in the type and percentages of unsaturated fatty acids. The factory consumption in 1937 was 40 million pounds, of which about three-fourths was used in the paint and varnish industries, especially in conjunction with domestically produced soybean oil. The remainder was used in the manufacture of linoleum, printing inks, and miscellaneous products.

The plant belongs to the mint family. Its seed is about the size of mustard seed and contains about 37 percent of oil. The seeds are small, do not all mature at one time, and difficulty is experienced in handling because of "shattering." Breeding may be necessary for improvement of plant habits and characteristics before it can be grown in our system of mechanized agriculture.

Rapeseed (Colza) oil.—In the United States rape has been grown almost exclusively as a forage and cover crop. Little seed is known to have been produced domestically, foreign seed being imported for planting and for use in birdseed mixtures. No rapeseed is known to have been crushed in the United States prior to 1934 or 1935.

Variable amounts of rapeseed oil have been imported annually, and in 1936 importations amounted to 73 million pounds. This oil is classed as being midway between nondrying and semidrying oils and contains about 50 percent of erucic acid, which has 22 carbon atoms in the molecule.

Rapeseed oil is used for edible purposes, as lubricant, both alone and mixed with mineral oils, and in the manufacture of rubber substitutes. The factory consumption in 1936 was 67 million pounds and in 1937 was 14 million pounds, of which 5 million pounds were used in the manufacture of shortening.

Safflower oil.—Safflower has been investigated in recent years as a possible oilseed crop for the northern Great Plains area and the Southwest. The oil belongs to the drying class and is well adapted for the manufacture of light-colored paints, varnishes, and enamels because of its nonyellowing characteristics. In India, where the plant has been grown for centuries, the blossoms have been used as a source of saffron dye, and the oil for edible purposes and also as a lamp oil. So far safflower oil has not been produced in commercial quantities and it has not been an item in international trade.

Sesame oil.—Sesame oil belongs to the semidrying or general-utility class of oils. In this country it is used largely in the production of food products and also directly as a salad and cooking oil. It has been used for a wide variety of purposes similar to those of cottonseed oil, but since it has the property of resisting rancidity longer than many other oils it is very desirable as the shortening ingredient in the prepared flour mixtures used for making pancakes, biscuits, etc.

The domestic supply of sesame seed and oil is obtained from the Orient, where the oil is used for edible and medicinal purposes, soap making, and as a lamp oil. The seed yields about 50 percent oil. The press cake is used as a fertilizer and stock feed. Amounts of the seed and oil imported have varied with such factors as import duties, world demand, and the price of domestic edible oils. The factory consumption of sesame oil in 1937 was 38 million pounds, of which 29 million pounds were used in the manufacture of shortening. The "apparent disappearance" was only one-half of 1 percent of the total domestic consumption of fats and oils in 1937. The seed is used to some extent on bakery products and in making various kinds of confectionery.

The pods are dehiscent, that is, they split open on drying and scatter the seeds, which is a serious deterrent to mechanical harvesting. Unless there is improvement of the plant by breeding and selection, domestic production of sesame may not become a profitable venture.

Sunflower oil.—Sunflower oil belongs in the semidrying class and has been used in the United States for edible purposes. The imports originate largely in Russia, where the sunflower has been grown for the oil from the seed and for potash from the ashes of the stalks. The consumption of sunflower oil averaged 25 million pounds annually from 1931 to 1936; it has been used largely for salad and cooking purposes. Owing to changes in the tariff, importations have almost ceased.

Domestic production of sunflower seed, which averaged 7 million pounds annually over the 10-year period 1927–36, centered largely in Illinois, Missouri, and California. The seed has been used almost exclusively for birdseed and for poultry-feed mixtures.

Tea-seed oil.—Tea-seed oil, imported largely from China, is similar in nature to olive oil, and has similar food and technical uses. Imports were of minor importance prior to 1935. They reached a peak of 27 million pounds in 1937 after a steady 6-year rise. Since that time imports have declined, due to materially lower market prices and increased world supplies of olive oil.

Minor oils.—Limited amounts of oils derived from grapefruit, lemon, orange, grape, melon, pumpkin, tomato, wild radish, mustard and locust seeds, and from peach, apricot, cherry, walnut, and pecan kernels are available, or potentially available, for use. These are, or may be, used for edible purposes, for soap making, and as drying oils.

PRESENT RESEARCH

Much of the research in progress or suggested in the introductory portion of the section on Oil Seeds and Crops is equally applicable to the miscellaneous oilseed plants and plant products just described. A number of plants, such as the babassu palm, could not be grown commercially in this country, while others like perilla and chia are naturally restricted to certain rather limited climatic and soil belts. On the other hand, safflower and rape can be grown over rather extensive areas.

Wherever oilseed-bearing plants are being considered as possible replacement crops, it is necessary to bear in mind that genetic and agronomic studies are essential to determine the effect of variety, soil type, climatic influences, etc., on the yield and quality of seed produced. Unless the oil yield per acre or the price of the oil is very high it is also necessary to develop uses for the byproducts—stalks, leaves, stems, and press cake—thus spreading the cost of production over several commodities.

These requirements are reflected in the type of projects enumerated under both the present and suggested research as it refers to miscellaneous oilseed plants and derived products. The following research projects are in progress:

1. Genetic studies for the improvement of various oilseed-bearing plants, especially with respect to mechanical harvesting and yield and quality of oil. One reported project has for its objective the increased yield of oil from soft-seeded pumpkins.

2. Agronomic studies concerning the adaptability, varieties, cultural treatment, climatic and soil requirements, etc., of safflower, perilla, chia, rape, and other oil-producing crops, and to development of mechanical harvesters. These are annual seed crops. Safflower and rape are adapted to the spring-wheat area of the central Great Plains and to the irrigated regions of the Southwest, and may have possibilities as a winter crop in southern California, New Mexico, and Arizona. Perilla and chia require long seasons. Perilla is adapted to the southeastern portion of the Cotton Belt; and chia, which is more exacting, must also be restricted to southern latitudes.

3. Research on problems of interchangeability and uses of all fats and oils with particular emphasis on problems involved in planting, production, taxing, and trade agreements.

4. Studies of price, competition, and interchangeability affecting the demands for oils by the soap industry, the paint and drying-oil industry, the oleomargarine industry, the vegetable-shortening industry, and other food industries.

5. The study and development of methods for the detection of adulterants in oils.

6. Several recent investigations on the chemical constitution and properties of the liquid wax and jojoba seed.

SUGGESTED RESEARCH

The various miscellaneous oils, excepting olive and sunflower oils, are not domestically produced in large quantities. Some of these oils may become items of importance in American agriculture to meet specific industrial needs. Suggestions for research projects relative to the whole group of these oils are as follows:

1. Intensification of the agricultural investigations relative to the production of perilla and chia seed for oil, and genetic studies to improve the growth habits of these plants especially with regard to overcoming the shattering of the seed.

2. Extension of present investigations on the production of rapeseed, including both genetic and agronomic studies, methods of harvesting, handling, storage, etc.

3. Intensification of the agricultural investigation of the production of safflower seed for oil.

4. Research seeking to develop a variety of hemp suitable as an oilseed crop but devoid of the drug properties. This would involve experimental plantings, probably in a number of localities where public opposition could easily develop.

5. Comprehensive investigation of sesame as a domestic crop, including genetic and agronomic studies, processing, and utilization in fields to which it is especially adaptable.

6. Studies on the possible production of domestic locust seed and tea seed and extension of present studies of plants as potential sources of oils, fats, and waxes, including an examination of such desert plants as hemp dogbane, prickly poppy, cats-claw, and native mesquites and palo verdes.

7. Investigation of the possibility of growing, harvesting, and processing jojoba seeds.

8. A study of the hydrogenation of the nonfatty jojoba oil and an investigation of the possible use of the hydrogenated product in finishing and polishing wood, metal, etc.

9. An investigation of the suitability of jojoba oil for dressing leathers, especially white leathers, since this oil is colorless.

10. A number of suggested investigations with reference to various minor oils include: The extraction of pecan oil from waste kernel particles mixed with shells for use as a possible substitute for olive oil in the textile industry; use of the phenolic constituents of cashew nuts and shells as a repellent in ship-bottom and other marine paints; debittering of oils derived from citrus seeds; reduction or prevention of the development of color in hempseed oil to permit its use in clear varnishes and light-colored paints.

11. Investigation of the tendency of rapeseed oil to polymerize spontaneously when used as a plasticizing agent; investigation of its lubricating properties and its use in oil lacquers.

12. Investigation of the possibilities of industrial utilization of various byproducts derived from the processing of miscellaneous seeds.

FRUITS, VEGETABLES, AND NUTS

Since much of the research dealing with fruits, vegetables, and nuts, particularly from the standpoint of utilization, is definitely inter-related, it appears best to group these commodities together in one section. The various products are discussed under the following subheads: (1) Tree Fruits, (2) Small Fruits, (3) Melons, (4) Vegetables, (5) Nuts, and (6) Processing Wastes. Processing wastes are included here because they are so closely related to the utilization of these commodities by industry. To gain an adequate picture of present and suggested research on any one fruit, it will be desirable to read the entire section on fruits. The same is true of vegetables.

TREE FRUITS

TROPICAL AND SEMITROPICAL FRUITS

CITRUS FRUIT

Citrus fruit represents an increasing proportion of the total fruit output of the country. The production of apples remains fairly stationary, but the production of citrus fruit has about trebled in the last 20 years. The uses of citrus fruit, other than as fresh fruit, have so far been limited chiefly to canning, both as fruit and as juice, and to extraction of oils, pectin, and citric acid or citrates for use in flavoring extracts, manufactured food products, carbonated beverages, and pharmaceuticals.

In recent years citrus crops have brought growers a gross income of around 150 million dollars annually. The scale on which plantings have been made, especially of grapefruit, indicates the probable development of a serious surplus problem within the next few years.

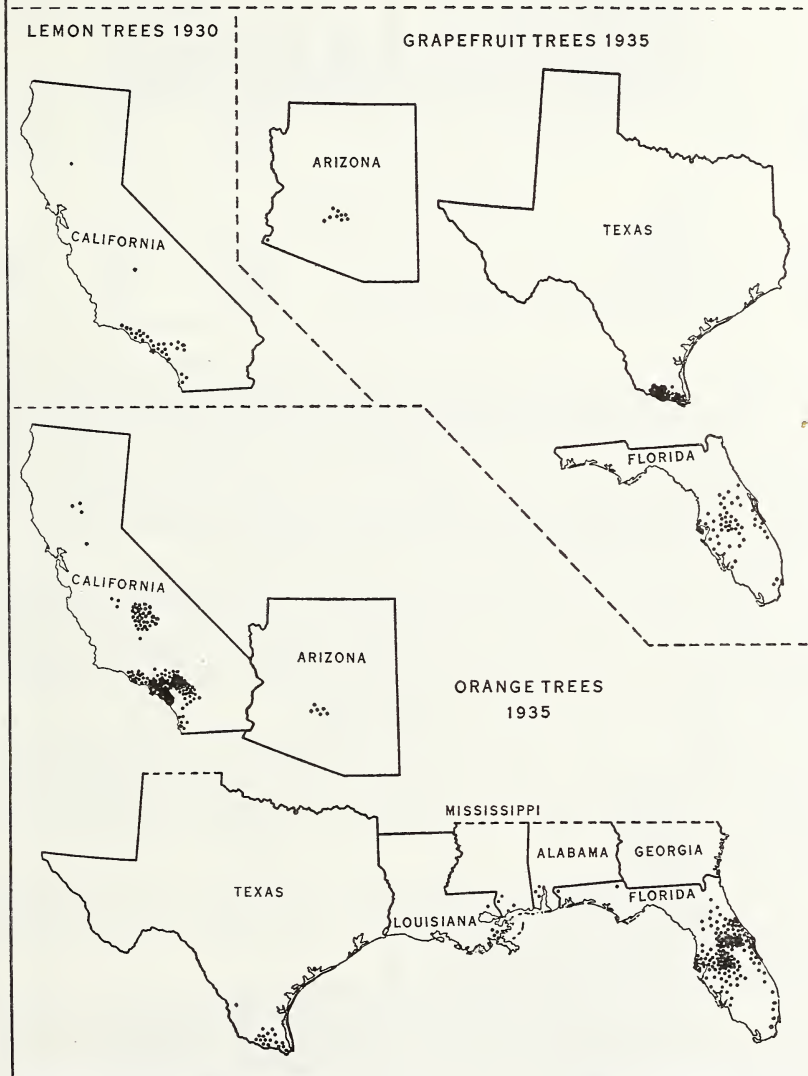
California and Florida together produce about 97 percent of the total orange crop. The production of oranges has more than doubled in the last 20 years. Of the 37,800,000 bearing trees estimated in the groves of California, Florida, Texas, and Arizona in 1938, nearly half are less than 15 years old, and a fourth are from 5 to 10 years old. With this large proportion of young trees yet to come into full bearing, it is considered likely that annual production during the next 5 years will average 75 million boxes or more, as against an annual output during the last 5 years averaging 58 million boxes. Most of the increase will be in Valencias and other late varieties.

The number of bearing grapefruit trees is five times as large now as it was in 1920. There are some 13,100,000 in bearing, of which about two-thirds are young trees that have not reached full production. It is considered likely that the present bearing acreage will permit an average production during the next 5 years of 35 million boxes. Judging from past relationship of supply and prices, this yearly output of grapefruit may mean decidedly low prices to growers.

Acreage devoted to lemons is virtually all in California. Bearing acreage is now estimated at 51,500 acres, having roughly 5 million trees. About 40 percent of the trees now in bearing are young and have not yet reached full production. However, world production of lemons has decreased in recent years, and there is no immediate prospect of a serious surplus with this crop.

ORANGE AND GRAPEFRUIT TREES, 1935 AND LEMON TREES, 1930

Each dot represents 100,000 trees



The production of oranges and grapefruit in various years from 1924 to 1937, the average price per box, and their farm value are shown in table 6.

TABLE 6.—*Production of oranges and grapefruit from 1924 to 1937, average price per box, and farm value*

ORANGES (7 STATES)			
Year	Production	Average season price per box received by farmers	Farm value
	<i>1,000 boxes</i>	<i>Dollars</i>	<i>1,000 dollars</i>
1924.....	30,328	3.07	92,986
1930.....	55,362	1.51	83,408
1934.....	63,988	1.27	79,602
1937.....	73,823	1.16	100,688

GRAPEFRUIT (4 STATES)			
1924.....	9,970	1.35	13,448
1930.....	18,934	.92	17,421
1934.....	21,367	.70	14,759
1937.....	30,878	.70	22,331

Large increases in the production of grapefruit may be expected, especially in Texas and Arizona, where over 90 percent of the trees have not yet reached full bearing. The same is true of California, where about 70 percent of the bearing trees are young. In Florida, on the other hand, nearly two-thirds of the trees have reached full production, and there is not likely to be so great an increase in this State. The western areas are growing mostly seedless grapefruit, whereas most of the seeded fruit is in Florida.

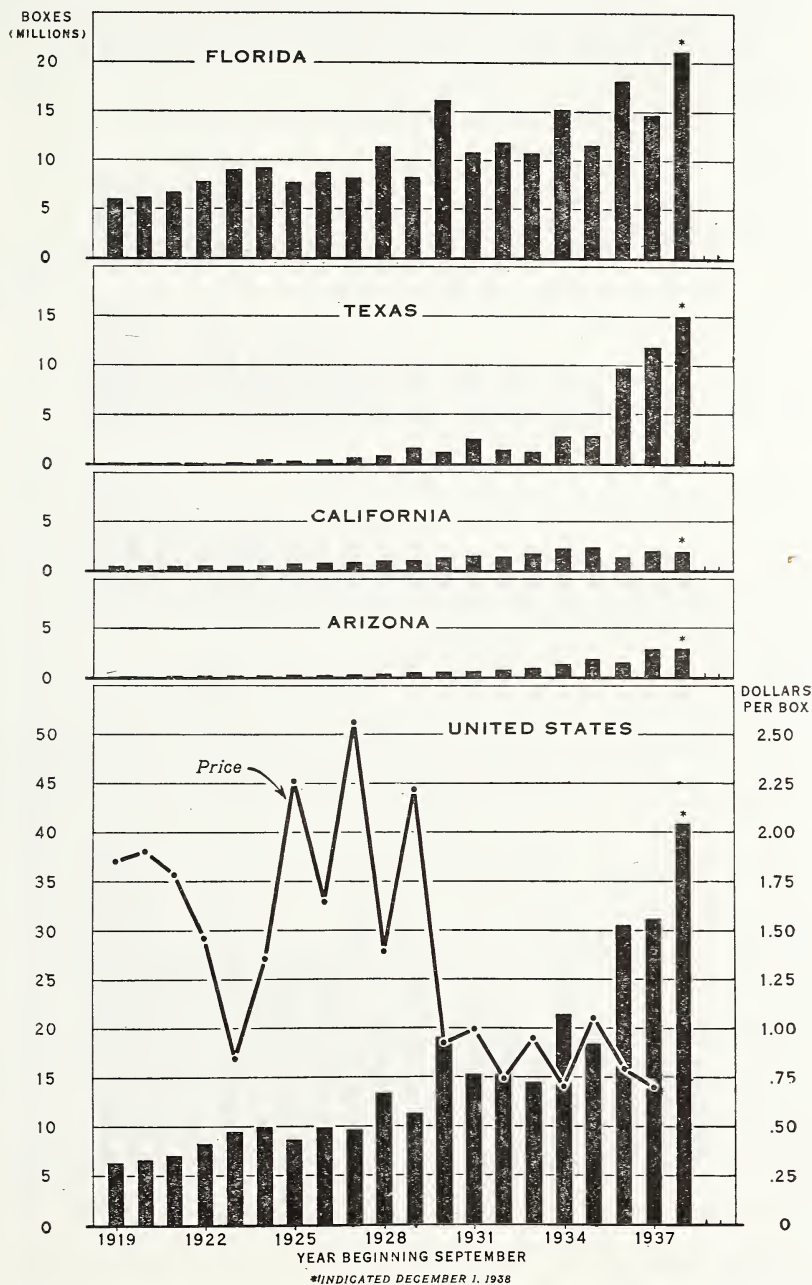
An idea of the extent of the orange-crop movement may be gained from the figures of carlot shipments. In recent seasons, California has shipped out from 45 to 71 thousand cars, Florida most of the time about 30 thousand cars, and Texas and Arizona small but increasing quantities. Texas shipped 1,755 cars in 1936-37, which, incidentally, was a 42,000-car season in California.

In an effort to help meet increasing market difficulties, the California-Arizona orange industry since 1935-36 has regulated shipments to fresh-fruit markets under a Federal marketing-agreement program for the purpose of maintaining and improving returns to the growers. Further efforts along this line probably will be made as time goes on.

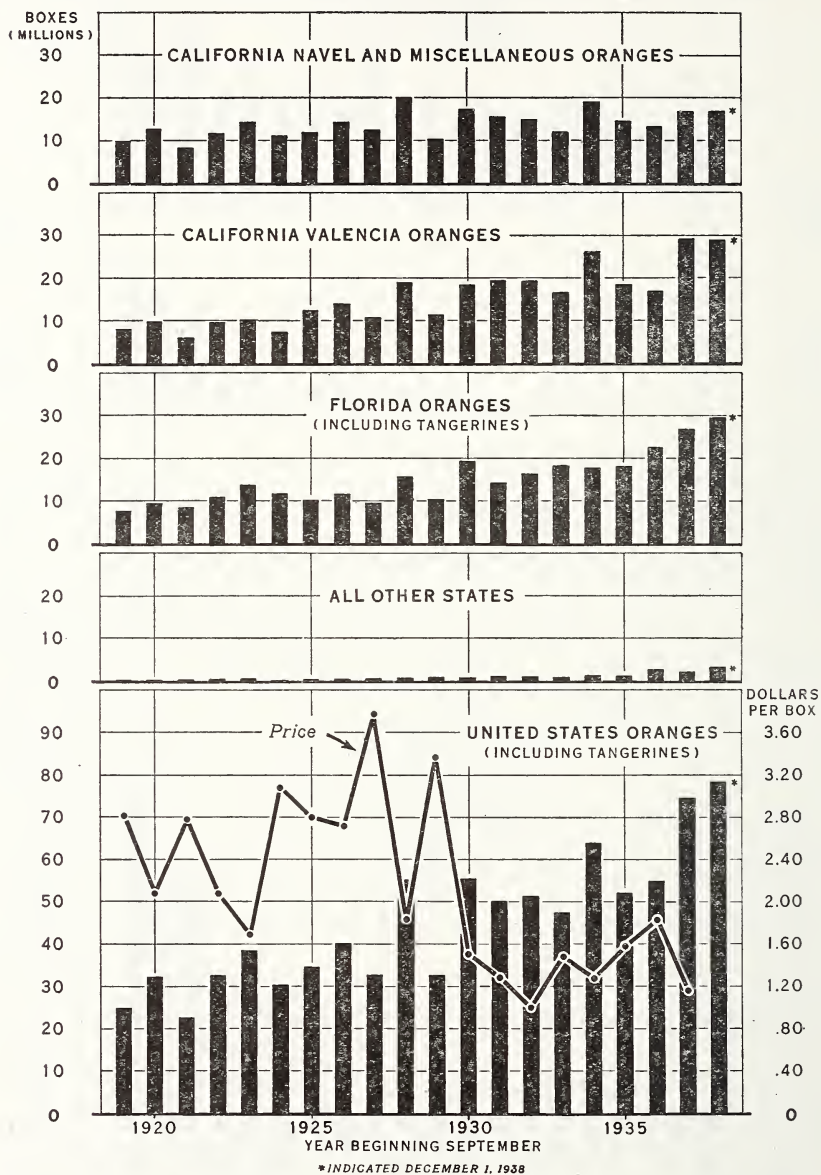
A fairly typical picture of grapefruit shipments is given by the 1936-37 figures, which included 20,400 cars shipped from Florida, 13,894 cars from Texas, and about a thousand cars each from California and Arizona.

Increasing quantities of grapefruit hearts and juice have been canned in recent years. Thus, a million cases of grapefruit sections were canned in 1928-29, and this item had grown to 4,301,000 cases in 1936-37. The canning of grapefruit juice increased from 205,000 cases (packed in Florida) in 1928-29 to 6,461,000 cases by 1936-37, about 62 percent coming from Florida canneries and 36 percent from Texas.

GRAPEFRUIT: PRODUCTION BY STATES, AND SEASON AVERAGE PRICE RECEIVED BY GROWERS, 1919-38



ORANGES (INCLUDING TANGERINES): PRODUCTION BY STATES, AND SEASON AVERAGE PRICE RECEIVED BY GROWERS, 1919-38



Important quantities of oranges have been utilized for the manufacture of juice, orange concentrates, canned oranges, marmalade, and various byproducts during recent years. Approximate quantities so used for the last four seasons are given in table 7.

TABLE 7.—*Quantity of oranges canned or used for concentrates, marmalade, etc., from 1934 to 1937*

Season	California and Arizona	Florida	Total
	<i>1,000 boxes</i>	<i>1,000 boxes</i>	<i>1,000 boxes</i>
1934-35.....	3,690	178	3,868
1935-36.....	1,727	213	1,940
1936-37.....	5,872	620	6,492
1937-38.....	4,247	1,250	5,497

The manufacture of these products has been confined largely to California, but quantities used for processing in Florida during the past 4 years have increased rapidly, and with prospects of still larger supplies of oranges in the future, an increasing manufacture of orange products can be expected in both States.

During the 1937-38 season about 43 percent of the total output of Florida and Texas grapefruit was utilized for the canning of juice and sections.

Exports of canned grapefruit have increased rapidly during the last few years. Total exports for the 1937-38 season probably will exceed the record exports of 1,159,000 cases in 1934-35. United States exports of oranges for 1935-36 amounted to a little over 4 million boxes, as compared with 2½ million in 1936-37 and 7 million during the first 10 months of the 1937-38 season. Spain has been the leading exporter of oranges (in 1935-36 amounting to 26 million boxes, or more than those from all other countries combined). However, the military operations in Spain have brought her exports of oranges down sharply and have placed the United States temporarily in a more favorable position as an exporter.

Citrus fruit is used almost entirely for food. Therefore, most of the present research undertakes to improve the appearance and quality of the fresh fruit or to lower the cost and improve the quality of that which is canned or otherwise preserved for marketing as juice, sections, or special products. Producers and the agricultural research agencies of the country have done a great deal of research on these food problems. Numerous investigations have been undertaken with the object of developing byproducts, and a smaller number with the purpose of developing nonfood uses either of fruit constituents or of the products found in the wastes of food-plant processing. From a survey of this research it is apparent that it falls largely into the following groups: Fresh fruit; processed fruit; byproducts and wastes. At least four classes of such research relate to the citrus fruit intended for market as fresh fruit.

PRESENT RESEARCH

The principal lines of research now under way are:

Fresh fruit.

1. Horticultural studies to determine the effect of variety, soil, climate, or season, fertilization, and orchard management on the condition or character of the fruit.

2. Gas treatment of fruit which has for its primary purpose speeding up the natural maturing processes in both pulp and peel, resulting in a product more attractive to the housewife without depreciation of nutritive value.

3. Preparation for market, including washing, coloring, waxing, and other types of mechanical or chemical treatment which make the fresh fruit more appealing to the eye, more easily and economically handled, and less liable to spoilage.

4. Storage and handling of the fruit, including wraps and wrapping, preservation by temperature and humidity control, refrigeration, gas treatment, and other methods of controlling spoilage.

Processed fruit.

A substantial part of the citrus crop is unmarketable as fresh fruit because of grading requirements or surplus above market capacity. Furthermore, at irregular intervals a variable proportion of the crop is ruined for the fresh market on account of freezing or orchard pests. The minimum loss due to these factors is from 5 to 10 percent of the total crop, and losses from surplus and defective fruit may run as high as 30 to 50 percent in some seasons. This material is utilized in processed food products, extracted for oils, pectin, and citrates, or is abandoned as waste and becomes a total loss.

Federal and State laboratories have assisted the organizations which produce and market citrus fruit, largely cooperative groups, and considerable technical research has been done on the problems involved. Although the primary product is still a food or a food drink, some of these researches approach closely to the problems which the regional laboratories will consider with respect to nonfood products. It is particularly evident that the byproducts of the citrus processing industries are potential raw materials for nonfood industrial developments.

At present, most of the researches on food processing fall within one or more of the following groups:

5. Processing of fruit for juice or juice concentrates.

6. Processing of fruit for sections or specialties, including freezing.

7. Canning, freezing, or otherwise preserving juice or sections. This is essentially a fruit-canning or fruit-preserving type of business on which a multitude of special industrial research projects are being carried out.

8. Biological studies for control of juice- or section-canning operations, including control of spoilage organisms and retarding or inhibiting enzymatic or other natural cell processes which may result in deteriorative changes in color, flavor, or odor. With citrus fruit, as in other fruit processing, biological control is fully as important as chemical control and good engineering.

9. Studies on the keeping quality of the products in storage, including depreciation in flavor or texture as well as actual spoilage or break-down of natural constituents.

10. Producing novel citrus products, such as citrus powder, citrus butter, and other food specialties.

11. Special studies on constituents of citrus-fruit products, including investigations on the gases in orange juice and the fatty bodies which affect the flavor and keeping quality of both juice and sections in cans.

12. Production of secondary food products, such as citrus oils and citric acid for food flavors and various medicinal and other uses.

Byproducts and wastes.

The production figures for citrus products given above indicate that huge quantities of cannery wastes accumulate each year. Probably not less than 175,000 tons of peel, seed, and rag (segment membranes) and undetermined amounts of liquid effluent must be disposed of in some way to prevent these wastes from becoming a nuisance, an orchard-pest breeder, or a health hazard. Byproduct studies on waste materials which result from citrus processing are being carried out at present by the interested industries and by Federal and State laboratories. Some of these projects, which now relate primarily to foods, are closely related to the purposes of the new regional laboratories and will need extension because of their nonfood implications.

13. Disposal or use of waste: This is an outstanding part of the whole present research program and of proposed investigations. Present researches are altogether inadequate to care even for pressing present needs in prevention of nuisance. Additional research is needed to solve this problem and to explore the possibilities of using the wastes as raw materials for industrial products.

14. Effluent control: The liquid wastes produced at citrus-processing plants present a peculiarly difficult problem in areas where they must be disposed of in streams. Research on this problem is being carried out under the urgent pressure of legal restrictions, especially in California, which prohibit the contamination of streams from canning, drying, and other processing plants.

15. Production of feeds from byproducts: Some attention is being given to this problem, but far more study is needed on the problems of drying, grinding, meal preparation, and increasing acceptability as feed by certain kinds of stock that do not relish the bitter constituent. Present studies should be greatly augmented because of the nonfood significance of the present investigations.

16. Nutritional studies on citrus byproduct feeds: These are urgently needed to determine whether such feeds have sufficient nutritional value to justify their production, or so little as to make their use as nonfood products more practicable. Present investigations are inadequate.

17. Utilization of cull fruit: Such studies, as distinct from the types of investigation above outlined, are necessary because the whole fruit, sometimes frozen, sometimes damaged, sometimes merely of unmarketable size or shape, must be taken into account.

SUGGESTED RESEARCH

The development of new industrial products as nonfood derivatives of citrus fruit appears to be possible. But before this type of work can be organized, more fundamental knowledge must be gained regarding the constituents of the various parts of these fruits as well as their utility and means for their isolation. The important studies of this kind which have been suggested are as follows:

1. A complete inventory of the constituents of citrus fruit: The studies should include the analysis, by the best chemical and physical methods available, of each of the parts of the fruits in an effort to determine its organic constituents and estimate the quantities of possibly useful constituents available for new industrial uses. It has been suggested that fundamental X-ray diffraction spectra, molecular weight, double refraction flow studies, and similar approaches to these problems be included in such a research program. This illustrates the need for ultramodern methods of research on very plebeian and practical commodities. After this fundamental knowledge is available, and in some cases without waiting for detailed results, a variety of studies should be started on the separation, properties, and possible uses of the major constituents known to be present. Several types of such research have been touched on lightly by present investigators or have been strongly recommended to the Department.

2. Separation of oils from both peel and seed. Improved methods of separating fixed oil from the seed and volatile oils from the peels should be investigated, and the influence of the method of recovery upon the properties of the oil should be determined.

3. Utility of oils and their derivatives: The fatty oils of the seeds in the natural state, hydrogenated, or otherwise treated may well have peculiar properties that adapt them for specific uses. Direct utilization of the volatile oils as scents or in perfumes may be possible, or certain odorous or flavoring constituents may be found useful. Some special derivatives appear to have cosmetic value. Other constituents, such as limonene from lemons, are terpene compounds. Few uses for these materials are known, but as soon as small quantities are available and adequate knowledge is at hand concerning their physical and chemical properties, new uses for them should be investigated.

4. Isolation of pectin: Pectin is one of the most important and prospectively useful constituents of peel and pulp. Improved methods for its preparation from these materials should be developed and the influence of these methods on the properties of the products should be studied. It will be necessary to make fundamental investigations of the properties of this compound and its derivatives.

5. Recovery of vitamins: The rapid expansion in the use of citrus fruits in the American diet is due in no small measure to their vitamin content. The feasibility of vitamin recovery from this source for commercial use deserves at least exploratory investigation.

6. Separation of glycosides: In the peel of all citrus fruits are compounds known as glycosides. The separation and preparation of these materials in usable form has been recommended. Some prospective medicinal uses as diet correctives are worthy of investigation. Studies of this sort should be undertaken in cooperation with other qualified research agencies when usable quantities are available.

7. Isolation and utility of miscellaneous organic constituents: Various organic constituents in the byproducts of citrus fruit are being recovered industrially, such as citric acid and other organic compounds and esters. However, further investigation of these compounds might well lead to other useful materials as well as extensive improvements in those processes now in use. Preparation of such products on a small scale would permit experimental studies on new uses. In some cases secondary derivatives would be required.

In other cases the constituents themselves, like the rare sugars, would find a direct market.

8. Chemical derivatives from constituents of citrus fruit: Synthetic secondary products may be made from some of the primary constituents of this fruit. For example, some of the derivatives of citric acid have been suggested as of possible commercial importance. One such compound, chlorotricarballylic acid, is already being investigated by one industrial unit. It typifies a wide variety of possible secondary products that might be made from any of the primary constituents which are found to be commercially recoverable at reasonable costs.

9. Fermentation studies: The processing of many of these materials by biologic methods, i. e., fermentation by bacteria, molds, or yeasts, should be considered. Fermentation studies may yield not only special alcohols but also a considerable variety of ketones, esters, and organic acids. The present wastes or byproducts of the industry should be investigated in order to determine what useful materials might be made from them by these biologic procedures in contrast with those made by ordinary industrial chemical methods.

Many of these investigations relate primarily to citrus fruit but will closely parallel like projects on other types of fruits, or in some cases on vegetables.

AVOCADOS, DATES, FIGS, OLIVES, AND PAPAYA

AVOCADOS

Avocado production in the United States is about 7,000 tons per year, valued at approximately \$1,000,000. The production is confined almost entirely to California and Florida, and practically all the fruit is shipped in the fresh condition. At the present time there is no real problem of surplus, since imports average about 3,600 tons a year, but it is estimated that the crop in 1939 will approximate 15,000 tons, or more than double the 1938 production. This yield from increased acreage may create a serious surplus problem. There is a considerable problem in the utilization of imperfect and wind-damaged fruit. These total about 6 percent of the total crop in a normal year, but may run as high as 50 percent in years of high wind or extremely cold weather.

PRESENT RESEARCH

At the present time there is very little research under way on the use of the avocado. Two lines of research are in progress:

1. The production of avocado cheese from the whole pulp.
2. The production of avocado flour from defatted pulp.

SUGGESTED RESEARCH

In view of the problem of disposal of cull and damaged fruit and the probability of surplus from increased acreage now coming into bearing, it seems highly desirable that research work on industrial utilization be undertaken. The following research projects have been suggested:

1. Develop a rapid, simple method for judging the maturity of the fruit in order to determine the proper time for picking.

2. Develop improved methods for transporting the fresh fruit. This can probably be done best through refrigeration and ventilation.
3. Investigate the vitamin content of the avocado and methods of preserving the nutritional quality of the fruit.
4. Study methods of extracting oil from the pulp.
5. Study the use of the oil in cosmetics, pharmaceuticals, etc.
6. Give further study to methods of preparation of avocado cheese, flour, and similar products.
7. Develop uses for the press cake from the pulp and seed after oil extraction.
8. Undertake fundamental chemical studies on the constituents of the avocado, and in particular on the oil and protein of the pulp and seed.

DATES

Date growing in the United States is confined largely to the States of California and Arizona. The annual production is approximately 3,500 short tons, and is expected to reach 10,000 tons by 1942, as new plantings come into bearing. It is estimated that of the annual production of 1,500 tons in Arizona, 1,000 tons, or two-thirds of the crop, is unfit for the fresh market. This is due largely to the poor varieties under cultivation and to improper handling of the fruit. In California at least 15 percent of the crop is low grade and should be diverted to byproduct use, since the marketing of poor dates is proving a hindrance in developing sales for the domestic date crop.

Methods for profitable disposal of low-grade and weather-damaged fruit will help to establish the industry on a permanent paying basis. In addition to the dates themselves, there are two sources of byproduct materials—the pits from drying sheds where pitted dates are packed and the prunings from the trees. About 10 percent of the weight of the date is seed. It is estimated that there were about 75 tons of seed in the diverted portion of the 1937 crop, and that there will be three times that amount 4 years hence. A large tonnage of prunings has to be disposed of each year. Such material is utilized for various purposes in Egypt and other countries of northern Africa and southwestern Asia, which provided the original stock for our date plantings.

PRESENT RESEARCH

The following lines of research are being carried on at the present time:

1. Date-breeding studies, including the various factors involved in inheritance of sugar content, color, earliness of fruiting, and the value of different males for pollination.
2. Extensive research on the various phases of date production, including testing of varieties, methods of pollination, irrigation, and related problems.
3. Considerable research on maturation, time of harvesting, and storage and curing conditions following harvest.
4. Spoilage of date fruit in relation to micro-organisms.

SUGGESTED RESEARCH

From those interested in the establishment of a permanent date-growing industry in this country have come the following suggestions:

1. Develop improved methods of storage, drying, and canning of dates.

2. Make studies on the best methods of preventing spoilage by micro-organisms.
3. Study the vitamin content of fresh, dried, and canned dates, and develop methods of preserving the nutritional value of the products.
4. Study the preparation of sirups and flavors from dates.
5. Develop methods for the separation of sugars from dates.
6. Make microbiological studies with view to producing alcoholic beverages, higher alcohols, esters, ketones, and organic acids.
7. Make fundamental chemical studies of the constituents of the date and seed.
8. Develop methods of extraction of protein and oil from the seed.
9. Develop uses for the fiber from the prunings of date palms.

FIGS

The commercial production of figs centers largely in California, with a less important area in Texas. The average annual production is about 81,000 tons, with a farm value of 1.98 million dollars.

Figs are marketed in three forms—dried, fresh, and canned or preserved. In 1937 dried-fig production in California amounted to 29,500 tons, while the production of figs for sale fresh and canned was approximately 10,000 tons. In Texas production of figs for preserving amounts to 1,610 tons.

The growing of figs in California for commercial markets has been on the increase. In the case of dried figs, production during the past 10 years has averaged nearly double what it was in the preceding 10 years; that is, about 20,000 tons as against 10,000 tons. The output of fresh and canned figs has increased steadily.

Commercial production in Texas has fluctuated widely during the last 15 years. From 1,180 tons in 1924 it reached a peak of 6,510 tons in 1928 and then fell rapidly to only 510 tons in 1932. The industry is coming back, however, as is indicated by the 1,610-ton crop of 1937.

Texas figs are entirely different from the varieties grown in California. They are marketed mainly as preserves. The fresh fig does not stand shipment, and climatic conditions are not suitable for sun drying.

Figs are used almost exclusively for food, either fresh, dried, canned, or preserved. Large quantities of dried figs are used by bakers and confectioners. A limited amount of the fruit is used in the preparation of certain types of therapeutic or medicinal proprietaries. About 25 percent of the total crop is low-grade, nonmerchantable material which should be diverted from market channels. This off-grade tonnage is the chief surplus problem in the fig industry, and is due largely to disease and insect infestation. Methods should be devised to utilize this type of material in an industrial program.

PRESENT RESEARCH

The survey revealed that a limited amount of research on figs is being carried on, which may be summarized as follows:

1. Morphological, cytological, and genetical studies, with especial reference to the improvement of commercial varieties for drying and freezing.

2. Development of improved methods for handling and processing for food.

SUGGESTED RESEARCH

Suggested research on figs covers a wide field, embracing both fundamental and applied studies, with emphasis on work leading to a solution of the cull problem.

1. Place genetic studies on a more fundamental basis.
2. Undertake breeding of figs to produce better quality fruit.
3. Make a detailed analytical investigation of the composition of different varieties of figs.
4. Improve methods for processing technique.
5. Develop new methods of processing figs to maintain the quality and nutritional character.
6. Develop new uses for black figs.
7. Develop methods for recovery of vitamins.
8. Develop methods for the recovery and concentration of the protein-splitting enzyme known as ficin.
9. Conduct fundamental studies on the biochemical action and composition of ficin.
10. Study the production of sugars from figs.
11. Study the production of levulose from cull fruit.
12. Investigate the production of higher alcohols, ketones, and organic acid from fruit.

OLIVES

Olive orchards were established in California by the early Spanish settlers, primarily for the production of olive oil. Early in the present century, it was discovered that ripe olives could be canned like other fruit. In 1936, 13,500 tons of ripe olives, or practically one-half of the entire olive crop, was canned; 11,500 tons were pressed for oil; and 1,340 tons were processed as "Greeks," "Sicilians," or "Spanish greens." According to the 1935 Census of Manufactures, the total California olive pack was valued at 8.2 million dollars. There is some commercial production in other States of the Southwest, but no data on utilization are available.

Unless there is a carry-over of processed material from one season to the next, there is no problem of surplus in connection with the olive industry. The only disposal problem is the question of finding remunerative outlets for the press cake, or pulp, from the oil mills. It is used to some extent as fuel at the plant but has been found unsuited for stock feed unless the pits can be removed. Oil content varies with the season, but on the basis of data for 1936, it is estimated that 6,000 tons of pits were discarded in that season. In addition, there is a comparatively small quantity of pit waste in processing pitted olives. Some work has been done on the treatment of the press cake to recover the 10 to 12 percent residual oil, which is used in the manufacture of soaps. There are possibilities, also, in the production of seed oil and seed press cake.

PRESENT RESEARCH

Inasmuch as olive production is so completely localized, most of the work in progress is being carried out in cooperation with agricultural experiment stations and olive processors. Projects now under way include:

1. Improvement in processing methods for food products.
2. Development of an improved method for recovery of low-grade oil from the press cake.

SUGGESTED RESEARCH

Most of the suggestions for research have had to do with improving of pickling and fermentation processes or improving the quality of the canned fruit. They may be listed as follows:

Food utilization.

1. Fundamental chemical study of fruit of different varieties at different stages of maturity.
2. Fundamental study to follow the chemical changes which take place during the pickling process.
3. A microbiological study of the pickling process with particular attention to the enzymes involved.

Nonfood utilization.

4. Continuation of the fundamental studies on olive oil and its derivatives.
5. Studies on the alkaline and acid hydrolysis of the press cake with particular attention to the recovery of proteins.
6. Further studies on the press cake with special reference to its use as a cattle feed.
7. Fundamental physical and chemical studies on the seed oil and its derivatives.
8. Fundamental study of the proteins of the olive seed.

PAPAYA

The papaya, known as the tree melon, is a subtropical fruit receiving some little attention as an orchard development in Hawaii, Florida, California, and possibly some of the other Southern States. The papaya is used either as fresh fruit, canned as the sliced or diced product, in the form of special fruit concentrates such as preserves, or as the bottled juice. This fruit is peculiar in that, in the partially ripened stage, it contains considerable quantities of a protein-splitting enzyme known as papain. This enzyme has found considerable use in medicine, and its use as a clarifying agent in the beverage industries is well established. Approximately 200,000 pounds of papain are imported annually. Comparatively little is produced in the United States, on account of labor costs involved in hand collection.

PRESENT RESEARCH

The following lines of research are under way:

1. Studies on the production of papaya for its enzyme content, and extensive studies on the enzyme itself.
2. Studies on improvement in canning and other processing methods for food use.
3. Development of an enzyme preparation for use as a meat tenderizer.

SUGGESTED RESEARCH

1. A complete chemical analysis of different varieties of papaya fruit.
2. Complete biochemical and physicochemical studies on the fruit and its extractives.
3. Study of vitamins of the fruit and development of methods for the recovery of vitamins and their concentration.
4. Fundamental studies on the variation of the enzyme content in different varieties of fruit and at different stages of maturity.
5. Development of economical methods for extracting papain from the fruit and from the entire plant.
6. Development of methods for the preparation of carpaine from the leaves.
7. Fundamental studies on the action of papain in connection with its use as a meat tenderizer.
8. Fundamental studies on the seed proteins to ascertain what constituents there are present which might find subsequent industrial utilization.
9. Fundamental studies on the composition and physical characteristics of the oil of the seed and its derivatives.

DECIDUOUS FRUITS

APPLES

The major apple-producing areas of the country are located in the State of New York, the Cumberland-Shenandoah Valley, and the Pacific Northwest. Other areas of rather intensive cultivation are in the Central West, including the Ozark region, southern Illinois, southern Ohio, and southwestern Michigan. In a general way, farm orchards are extensively scattered throughout the northeastern part of the country.

The chief producing States are Washington, which in recent years has produced an average of 31 million bushels annually; New York, 17 million bushels; and Virginia, 12 million bushels; followed by Pennsylvania, California, and Michigan. Of a total average annual apple crop estimated at 150 million bushels, about 90 million bushels represent the average commercial or market crop, produced in what may be designated as the commercial type of orchard. The apples from these orchards make up the real supply in the channels of trade, although in some years rather large quantities of apples produced in farm orchards are sold fresh.

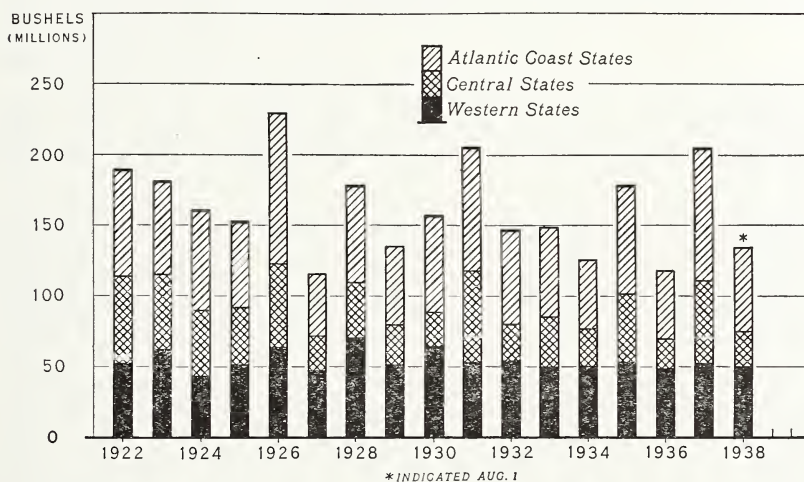
The number of apple trees in the country has been declining for many years. In 1935 there were in the United States about 100 million apple trees of all ages. This was less than one-half the number reported in 1910 and 14 percent less than that in 1930. Since 1930, plantings have been light and removals have continued. The result has been a further decrease in trees of both bearing and non-bearing ages. In 1935 only about 17 percent of the trees were not of bearing age, whereas in each of the three previous census enumerations about 24 percent of the trees reported had not come into bearing. In other words, the number of young trees has been steadily declining, and the indications are that this proportion will continue to decrease for several years, should the recent low rate of planting continue.

Because the reduction in the number of trees in the last 15 years has been largely due to the removal of poor trees from unprofitable orchards, and because of better care given bearing trees, the actual production of apples has not decreased in proportion to tree removals. For example, in 1935 the total number of trees of bearing age was 28 percent less than in 1920, but total production had declined only 8 percent.

Apple production in the last 3 years (1936 through 1938) has varied tremendously, ranging from 117.5 million bushels in 1936 to 211 million bushels in 1937. The average of these three crops—153 million bushels—is about what can be expected with average growing conditions. If the number of bearing trees continues to decrease at the same rate as during 1930–35, if the yield per tree continues to increase at an average rate of 1 percent a year, and if growing conditions are average, production should be about 150 million bushels by 1945. If, however, the shrinkage in bearing trees continues at the rate reported between 1925 and 1935, the total crop by 1945 should average about 140 million bushels.

The average price received by farmers for apples during the last 20 years has ranged from a maximum of \$1.75 a bushel immediately following the World War (1919), to a minimum of 60 cents in 1932. Prior to 1932, the average farm price of apples had been above a dollar a bushel most of the time. Only in one season (1936) since 1932 has the average price been above that figure. During the past half dozen years the average price to apple growers has been only about 70 cents a bushel.

APPLES: U. S. PRODUCTION BY REGIONS, 1922-38

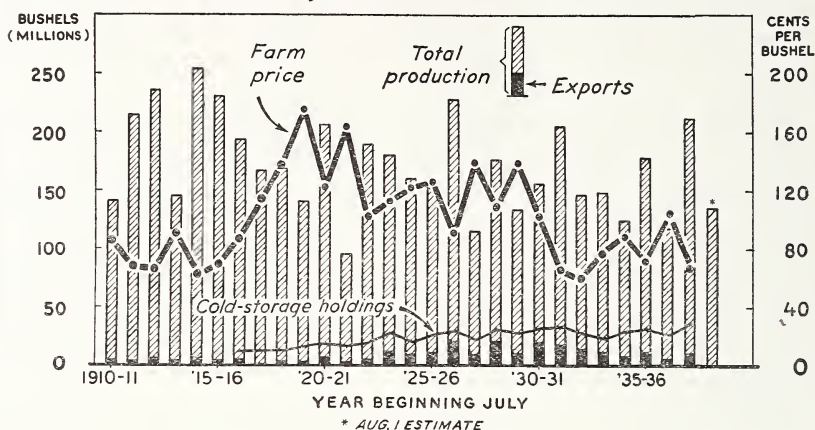


U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

From the standpoint of an actual or potential surplus problem, the apple situation is as serious in the Northwest as anywhere in the country. This is because of that region's long distance from domestic markets and its considerable dependence upon the export trade.

Apples: Production, Cold-Storage Holdings, Exports, and Price Received by Producers, United States, 1910-38



U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

Apple production in the 11 Western States, taken as a whole, has been fairly stable in recent years at 50 to 55 million bushels a year. This group of States normally produces a little over a third of the total crop (table 8).

TABLE 8.—Apple trees and production by regions, 1932-36 average

Item	Western region	Central region	Eastern region
Production.....million bushels..	51.3	31.3	60.7
United States crop.....percent..	35.8	21.8	42.4
Bearing trees.....millions..	11.6	34.1	36.8
Trees of bearing age.....percent..	87.8	79.1	84.2
Average yield per bearing tree.....bushels..	4.4	.9	1.65

Because of the increase in the use of other table fruits and fruit juices, the apple has met with very serious competition in home markets. The foreign market has also been curtailed. Shipments for the 5-year period 1927-31 averaged 17.5 million bushels annually, while for the 1932-36 period the average dropped to 10.6 million bushels.

In spite of somewhat decreased production, a tremendous surplus of high-grade fruit has resulted, especially in years of high yield. In 1932, 1933, and 1935 apples not harvested on account of market conditions are recorded as having reached the appalling totals of 4.2, 4.6, and 4.0 million bushels, respectively. In addition to this large but variable surplus not harvested, the large amount of cull fruit graded out at the packing plants every year may average about 120,000 tons.

A great variety of products are made from apples. Apple-products industries use an average of approximately 31 million bushels of fruit per year for food processing, distributed about as follows:

	<i>Bushels</i>
Cider and vinegar—10 percent of total production.....	16, 000, 000
Dried apples—4 percent of total production.....	6, 500, 000
Canned apples—3 percent of total production.....	5, 000, 000
Canned apple sauce—1.2 percent of total production.....	2, 000, 000
Brandy—1.1 percent of total production.....	1, 800, 000

In addition to the problem of surplus, the apple industry is confronted with the question of disposition of processing wastes. These include approximately 25,000 tons of pomace remaining from about 16 million bushels pressed for juice, 22,000 tons of waste from drying plants in the form of skins and cores, and 17,000 tons of cannery waste.

In some localities the wet waste is hauled away by farmers and either fed fresh or ensiled for winter feeding. In general, where any attempt at salvage is made, the wet waste is dehydrated for storage and subsequent use in the extraction of pectin, or it is sold to manufacturers of mixed feeds, or ground and used as fertilizer. Apple waste may enter also into the manufacture of jelly-base and apple brandy. (See Processing Wastes.)

PRESENT RESEARCH

In the United States, present research on apples deals primarily with food uses. Producers and agricultural agencies have done a great deal of research on these food problems. Numerous investigations have been undertaken with the object of developing byproducts, but relatively few studies have been made for the purpose of developing nonfood uses of fruit constituents or of the wastes of food-plant processing. The survey of the research on apples indicates that it falls largely into the following four groups: Fresh fruit, processed fruit, byproducts, and wastes.

Fresh fruit.

1. Genetic studies, or the development of new or improved varieties, from the points of view of size, color, flavor, texture, blossoming time with relation to frosts, date of maturity, keeping quality in storage, and shipping quality.

2. Horticultural studies, which have for their purpose the determination of the effects of variety, soil, climate or season, fertilization, and orchard management on the condition or character of the fruit that may be harvested.

3. Control of diseases and insect pests, including pathological and entomological studies, and work on dusts and sprays, new insecticides, and insect attractants.

4. Preparation for market, including washing and other kinds of mechanical or chemical treatment which make the fresh fruit most easily and economically handled. Such treatment has for its object the removal of dust and dirt and of spray residues. It must preserve or enhance the appearance of the fruit and at the same time put it in condition to meet legal standards without in any way affecting its storage quality.

5. Storage and handling of the fruit, including questions of wrapping, preservation by temperature and humidity control, refrigeration, the use of inert gas, and other methods of control of spoilage and deterioration due to micro-organisms or to natural physiological break-down, which result in deterioration in color, flavor, or texture.

6. Studies on the composition and utilization of the waxy surface coating.

Processed fruit.

Producer groups as well as agricultural agencies have done a considerable amount of technical research on the problems involved in the manufacture of the various apple products. Although the primary product is still a food or a food drink, some of these researches approach closely the problems which the regional laboratories will consider with respect to nonfood products. It is entirely possible that some of the byproducts of this food processing may be potential raw materials for nonfood industrial developments. At the present time, within the processed food divisions, most of the researches fall within one or more of the following groups:

7. Processing of fruit for juice, including still and carbonated juice, cider, and brandy.

8. Processing of juice for vinegar, juice concentrate, bottler's and table sirups, or jelly.

9. Processing fruit for drying and prevention of darkening in sliced chilled fruit for the pie trade.

10. The canning of sliced apples, apple sauce and apple butter, essentially fruit canning or fruit preserving type of business, on which several special research projects are being carried out.

11. Studies on methods for production of juice that will not cloud on standing. At present bottled juices tend to develop the slow formation of a deposit which clouds the juice.

12. Novel apple products, such as apple powder, canned baked apples, apple "leather" (dried apple roll), and other food specialties.

13. As a nutritive principle, apple waste has had limited experimental use as an ingredient in fish foods.

14. The therapeutic use of apple concentrate to furnish galacturonic acid as a precursor of mucin in the treatment of ulcers, toxemia of pregnancy, and other intestinal disorders. This field has just been touched upon and deserves further consideration.

15. Therapeutic use of apple powder in the treatment of infant diarrhea.

Byproducts and wastes.

The only researches disclosed by the survey on nonfood uses of apples were:

16. Improving methods for the recovery of pectin.

17. Scant research on apple seeds which have been ground and pressed for recovery of oil. This was only preliminary in nature and is worthy of further exploration as to properties of the oil and constituents of the press cake.

18. Waste disposal as a nuisance is receiving some attention but it is a problem that needs further study.

SUGGESTED RESEARCH

Because of the increase in competition between apples and other table fruits as foods and the exceedingly large surplus, apple growers' associations realize that it is essential that new nonfood or novel uses be developed for apples if normal production, from the present plantings, is to be continued. Because apples and apple byproducts

have always been regarded as food or feeds, comparatively few suggestions were received by the survey for specific nonfood research projects. But before this type of work can be organized, it seems desirable that agricultural, biological, and chemical investigations on the varieties of apples and the effect of fertilizer and types of soil thereon be made, and that more fundamental knowledge be acquired regarding the constituents of this fruit. The most fundamental of such studies which have been suggested are as follows:

1. A census of constituents of apples of different varieties; such studies should include the analysis of the skin, fruit flesh, and seeds in an effort to determine what they contain, and in what quantities the possible useful constituents are available for industrial utilization.

2. After this fundamental knowledge is available, and in some cases without waiting for detailed results, a variety of studies should be started on the preparation, properties, and possible uses of some of the major constituents known to be present. Several types of such research have been touched upon by present investigators or have been recommended to the Department. Methods should be developed for the recovery of galacturonic and ursolic acids, and these in turn may possibly find industrial use as bases for the synthesis of new products. Recovery of malic acid for use as a dye mordant has also been suggested.

3. Pectin is one of the most important and prospectively useful constituents of the pulp and peel. New or improved methods for its extraction from these materials should be developed, and the influence of the various methods on the properties of the resulting products should be studied. It will be necessary to make very detailed investigations on the properties of this compound and its derivatives. It is of fundamental importance that the chemical and physical nature and properties of pectins from different sources as extracted by different methods be determined.

4. Specific studies suggested for pectin are the hydrolysis of pectin, including the effect of enzymes, acids, etc., in the cold and during heating at different rates and to different temperatures, in order to determine the effect of these factors on the physical state and chemical composition of the treated material.

5. The feasibility of recovery for commercial use of certain vitamins known to be present in apples deserves at least exploratory investigation.

6. The peel of the apple is known to carry certain waxy compounds. The feasibility of recovery for commercial use of wax from this source deserves more intensive investigation.

7. Apple-seed oil should be investigated further and methods of separation should be developed. The influence of the method used for recovery upon the properties of the oil would require attention. The physical and chemical characteristics of the oil should also be investigated.

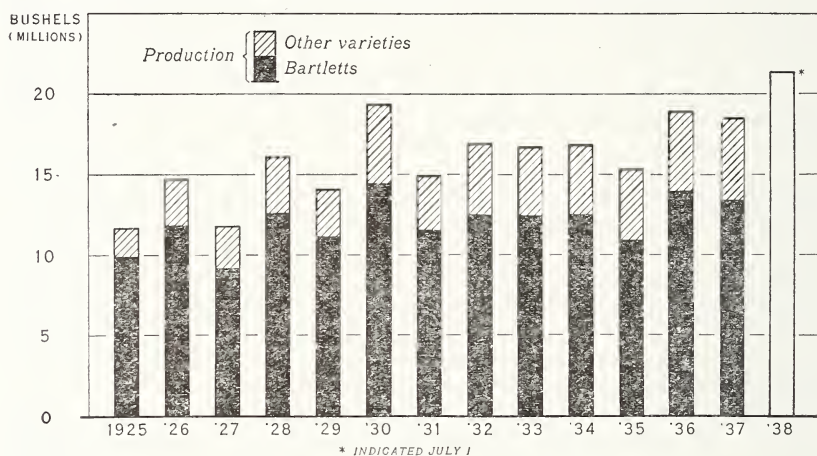
8. Improved methods for the drying of pomace and waste products should be developed which would permit indefinite storage for subsequent industrial utilization and remove potentially valuable material from the nuisance class.

NOTE.—Methods developed for the fundamental study of apple constituents and for the industrial utilization of apple culls and processing wastes should be easily adaptable to similar studies on pears.

PEARS

Of the somewhat more than 16 million bearing pear trees in the country, there are scattered acreages throughout the eastern third, and highly concentrated areas of production in the three Pacific Coast States. The national crop of pears is approximately 26,000,000 bushels, having a value of almost \$20,000,000. From 65 to 70 percent of the crop is produced in the western producing area. Pears are marketed as (1) fresh, (2) canned, and (3) dried. About 20 percent of the crop is canned. Pears for drying come largely from surplus production, and therefore the quantity dried may vary widely from one season to the next. More than 50 percent of the dried product is exported. The market is easily glutted by drying too many or by a falling off in exports.

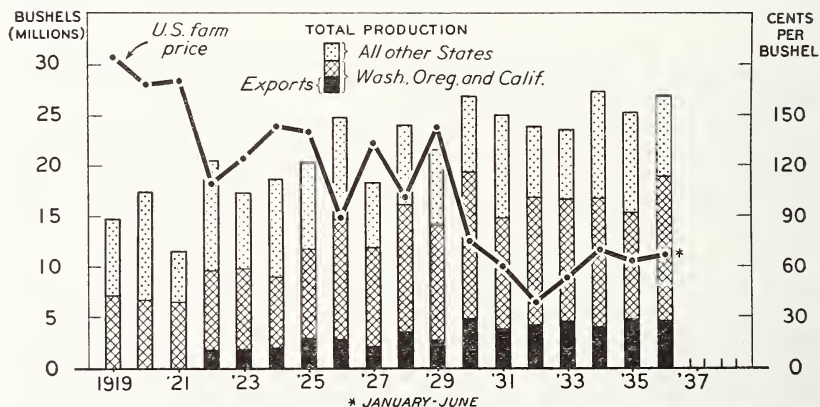
PEARS: WASHINGTON, OREGON, AND CALIFORNIA
PRODUCTION BY VARIETAL GROUPS, 1925-38



U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

Pears: Production, Exports, and Farm Price



U. S. DEPARTMENT OF AGRICULTURE

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PRESENT RESEARCH

It is apparent that comparatively little work is being done on the industrial utilization of the pear crop, especially the surplus and cull fruit for uses other than as food. From the fact that 22 percent, or about 5,700,000 bushels, of the crop is cull and waste, it is evident that some program should be undertaken to remove this material from the market and provide an outlet through industry. The research under way at the present time is largely devoted to:

1. Breeding for better varieties.
2. The effect of soil and irrigation on the quality of the fruit.
3. The handling of market pears and the economics of the pear situation.
4. Production of sirup, juice, and frozen pulp.

SUGGESTED RESEARCH

Projects suggested for the utilization of cull and surplus pears and processing wastes may be listed under two heads:

Food uses.

1. Determine the vitamin and general nutritional values of the various varieties of fruit.
2. Improve the methods of pear handling, transportation, and canning.
3. Investigate the freezing of pears and the production of beverages and table and fountain sirups.

Industrial uses.

4. Carry on fundamental chemical investigations on the constituents of the various varieties of pears.
5. Develop the production of higher alcohols, ketones, aldehydes, and organic acids through the use of bacteria, yeasts, and molds.
6. Investigate the recovery of waxy constituents of the fruit.
7. Develop methods for the extraction of pectin from cull and waste material.
8. Develop satisfactory methods for treating cannery effluents to recover valuable constituents and to prevent stream pollution.

STONE FRUITS

This title includes peaches and apricots, cherries, plums, and prunes. Dates and olives, the only other stone fruits of commercial importance in this country, are covered in the section on Tropical and Semi-tropical Fruits, page 154.

These fruits all rank high in acreage and farm value, and all are processed in large quantities for food consumption, by canning, drying, or freezing. Their processing wastes, especially the pits or stones, bulk large and are capable of furnishing industrial products far too valuable to be disregarded. (See section on Processing Wastes, p. 196.)

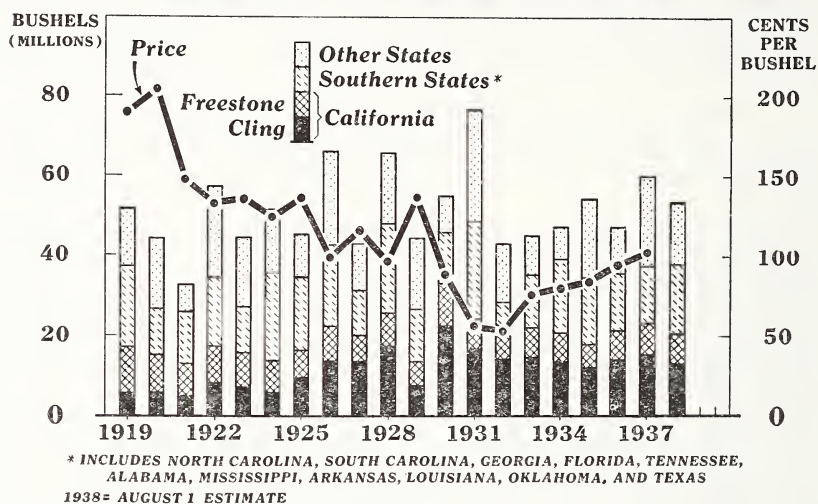
PEACHES AND APRICOTS

The peach crop ranks third among fruit crops in the United States, peaches being exceeded in farm value only by apples and oranges. The marketed crop averages over 1.3 million tons annually, with a

farm value ranging from 30 to 60 million dollars. Peaches are grown in 40 States, the production ranging from about 500 tons in New Hampshire to 300,000 tons and more in California. Georgia ranks second, with about 130,000 tons.

The bulk of the crop in the Eastern States, mostly of freestones, is grown for the fresh market. There is some canning, and a small development in quick freezing, still in the experimental stage.

Peaches: Production and Season Average Price Received by Producers, 1919-38



U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

California, always the home of the peach-canning industry, has averaged more than 85 percent of the known world pack for the last 5 years. In addition, this State has provided more than 40 percent of the world production of dried peaches.

The clingstone peach has been developed primarily for canning, and comparatively few clings reach the fresh market. Freestone peaches are raised both for market and for drying. Over 60 percent of the freestone peach crop is dried. In recent years the drying of clingstone peaches has been competing with and lowering the market for the freestones. This is partly due to the fact that the clingstones for drying are byproducts or surplus from the canning industry.

As with all tree crops, the problem of disposal in maximum crop years becomes acute. Even in normal years, cull peaches average approximately 17 percent of the total crop. In addition, there is always the problem of waste from canneries and drying yards. Both canned and dried peaches are pitted, and pit waste alone may run as high as 65,000 tons. This material has an appreciable salvage value, the kernels for both volatile and fixed oils and their stony covering for fuel or activated charcoal. There are also immense quantities of trimmings, skins, and liquid effluent which are now wasted and whose cost of disposal is an added charge against the final product.

In all probability, 90 to 95 percent of all the apricots grown in this country are produced in California. Other Western States, including Oregon, Washington, Idaho, and Utah, contribute comparatively small quantities. California's average annual production is about 225,000 tons. The 1937 crop was the largest on record, totaling 281,000 tons.

Most of the apricot crop is dried or canned, less than 10 percent reaching the fresh market. On the fresh basis about 162,000 tons are dried and 44,000 tons are canned. California supplies the world with dried apricots, 45 to 50 percent of the dried product being shipped abroad, mostly to European countries. From 14 to 24 percent of the canned pack also goes to foreign markets. Apricot pits available for industrial utilization accumulate, according to estimates, at the rate of about 1,380 tons annually.

PRESENT RESEARCH

Research on apricots and peaches now in progress has for its ultimate objectives the production of high-quality fruit for the fresh market or for processing, and the development or improvement of processing methods for conserving for food use that part of the crop not marketed fresh. Such work may be summed up as follows:

1. The development of new or improved varieties that (1) will withstand spring frost damage and (2) are adapted to specific purposes, such as fresh market, canning, and frozen pack.

2. A study of factors affecting size and quality of the fruit, such as thinning, soil moisture, and irrigation.

3. Methods of combating diseases and insect pests.

4. Methods of inhibiting darkening due to enzyme action in dried and frozen-pack fruits.

5. Development of new methods of handling varieties now grown in order to extend marketing range, such as frozen pack for home and institutional use; canned or frozen pulp for the ice-cream and soda-fountain trade; juices or nectars; and other specialty products.

SUGGESTED RESEARCH

Many of the suggestions received deal with food uses, and relate to extension of research on problems now receiving study. There are also many suggestions for work on industrial utilization of pits and kernels, and recovery of organic compounds from other wastes. These suggestions may be summed up as follows:

1. Study the enzyme systems of such fruits with a view to control of ripening, storage, etc.

2. Study the composition of the fruit in relation to sulfur dioxide retention during the drying process.

3. Develop improved methods of canning, freezing, and drying, especially for the control of enzyme activity.

4. Investigate the preparation of sirups, nectars, toppings, and similar products.

5. Investigate the extraction and use of pectin from cull fruit and wastes.

6. Try to develop methods for the extraction of odors and flavors and their use in perfumes and confections.

7. Develop uses and methods for handling peach and apricot pits, with special reference to the production of activated carbons and a study of their absorptive powers.

8. Determine the character of the oils and proteins of the kernels.

9. Study the pit oil and its possible use in pharmaceuticals such as cosmetics, shaving creams, etc.

10. Develop methods for recovery of amygdalin.

11. Study the utilization of solid cannery waste by microbiological means.

12. Develop methods for the disposal of liquid cannery wastes.

13. Make fundamental chemical studies on the organic constituents of peaches and apricots.

14. Make a fundamental study on the chemical constitution and physical-chemical characteristics of pectin from peaches and apricots.

CHERRIES

Cherry production is a 14-million-dollar industry. Annual production ranges from 115,000 to 140,000 tons. There are two well-defined centers of commercial cherry production. An eastern belt extends from Wisconsin through Michigan and Ohio to New York and Pennsylvania. A large part of the eastern crop consists of red sour, or "pie cherries." Western production, which is not quite so large as that of the Eastern States, is very largely sweet cherries. Michigan puts up practically one-half of the entire pack of red sour cherries, and the three Pacific Coast States pack about 95 percent of the total output of canned sweet cherries. In addition, 10,000 to 17,000 tons of sweet cherries are barreled in sulfur "brine," for later use in processing maraschino type cherries, or for inclusion in canned fruit cocktail or salad fruit.

The cherry crop offers a problem not only in market surplus, but also in damaged cull fruit. Cherries are very susceptible to cracking if rain falls at picking time. The ripe cherries crack from expansion and in some years nearly the whole crop in certain localities is lost for this reason. Tree fruits offer a serious surplus problem since it takes a number of years for the trees to come to bearing, after which they continue to bear whether a market is available or not. For example, it is estimated that 800 carloads of cherries were produced in 1938 in the Yakima Valley in Washington. Of this crop, only 425 cars were shipped, including shipments to canneries. The remainder was either not harvested or was unsold. In the Lewiston district of Idaho, of 100 carloads produced per year, 50 to 80 cars are estimated as constituting surplus and waste.

It has been estimated that during the 4-year period 1933-36, the harvested cherry crops of the United States were utilized about as follows: Canned, 26 percent; barreled in brine, 11 percent; frozen packed, 7 percent; marketed fresh or purchased by brokers or city manufacturers, 56 percent.

PRESENT RESEARCH

The research programs under way at the present time for the most part are directed toward:

1. Development of new and improved varieties.

2. Studies on the effect of such factors as climate, soil, and fertilizers on production and quality.

3. Methods of combating diseases and insect pests.
4. Investigations on the factors influencing the cracking of sweet cherries.
5. Proper brining methods, and the elimination of spoilage in brined cherries.
6. The preparation of concentrates, juices, sirups, and frozen pulps.

SUGGESTED RESEARCH

The present program is not broad or extensive enough to relieve the serious problem of surplus and waste cherries, and the following projects have been suggested in the belief that intensive work may point the way to economic diversion of part of the crop into industrial channels.

1. Study the factors which influence the cracking of sweet cherries.
2. Make vitamin studies on the various varieties of cherries and develop methods of preservation of the nutritional qualities of the fruit.
3. Develop more satisfactory methods for the dehydration of the fruit, preparation of concentrates and sirups, and the brining or preparation for maraschino cherries.
4. Make fundamental chemical studies on the constituents of the cherry. These include the oil and protein of the pit, volatile flavoring constituents of the flesh, and the pectic material.
5. Develop methods for the separation of the pectin, volatile oils, and pigments from cherries.
6. Develop methods for extracting oil from cherry kernels.
7. Investigate the preparation of organic acids, alcohols, and aldehydes, by the use of bacteria, yeasts and molds, from waste cherry material.
8. Investigate the preparation of activated carbons from pits, and make physicochemical studies on the absorptive properties of these carbons.
9. Develop satisfactory methods for the disposition of cannery effluents.

PLUMS AND PRUNES

All prunes are plums, but not all plums are prunes. A prune may be defined as a plum that will not ferment when dried without removing the pit.

Plums have a farm value of 1.3 to 2.4 million dollars a year. The canned pack averages just under 200,000 cases a year. The industry centers in Michigan and the Pacific Coast States, with New York and other States contributing small amounts.

Prunes are grown almost entirely in the Pacific Coast States. Oregon and Washington raise mostly Italian prunes, while in California the French prune is the chief variety grown. Comparatively few fresh prunes reach the retail market, the great bulk of the prune crop being dried. Both fresh and dried prunes are canned, and the quick freezing of prunes and prune pulp and of prune juice or nectar is a growing industry. The average annual production of 230,000 tons of dried prunes represents about 580,000 tons of fresh prunes with a farm value of about 15 million dollars.

While approximately 600,000 tons of plums and prunes are processed annually, there is comparatively little processing waste, since the canned and dried fruit is neither peeled nor pitted. Problems

facing the industry are surpluses in years of maximum production, discards from sorting tables, and nonmerchantable dried fruit.

Due to a decline in exports and to the competition of fresh fruits, canned fruits, and juices, the dried prune market has fallen off until the most serious surplus of the dried fruit industry is in this field.

PRESENT RESEARCH

Present research, from the point of view of production, is similar to that outlined for other stone fruits. From the standpoint of utilization, research is mostly concerned with:

1. The production of specialty products in the food field, such as sirups and concentrates.
2. The development of methods for the disposition of wastes.

SUGGESTED RESEARCH

According to research workers and leaders in the industry, the above program should be fortified by active work along the line of the following suggested projects:

1. Conduct vitamin studies on fresh and canned prunes.
2. Improve the methods of handling, drying, and transporting with a view to retaining the maximum nutritional qualities.
3. Study the value of prunes in the treatment of anemia and other disorders, especially in infant feeding.
4. Investigate the digestibility of prunes for ruminants and other animals.
5. Investigate the extraction of pigments, flavors, and odors from flesh and pits.
6. Conduct microbiological studies on the fruit and pit meal with the view of obtaining higher alcohols, ketones, aldehydes, and organic acids.
7. Study the extraction of fixed and volatile oils from prune pits.
8. Investigate the possibilities for the manufacture of activated carbon.
9. Investigate the products of destructive distillation of waste dried prunes, pits, and cannery waste.
10. Develop methods for the disposition of cannery wastes and effluents.

SMALL FRUITS

GRAPES AND RAISINS

Grapes are grown throughout the United States, and there are commercial vineyards in almost every State. By far the most important growing area is in California, followed by western New York and southwestern Michigan.

The only fruit crops outranking grapes in farm value are apples, oranges, and peaches, in the order named. The annual grape crop has averaged over 2 million tons in recent years and represents a cash income of from 40 to 50 million dollars a year. The bearing acreage is at least sufficient to maintain production on the present high level. California raises wine, raisin, and table varieties. Eastern grapes are grown for juice, wine, and fresh market. The California crop averages more than 85 percent of the total. The crop is utilized

in the form of (1) table grapes, (2) raisins, (3) juices, (4) canned grapes, and (5) wine.

The surplus problem in the grape industry can often be relieved by diversion of one type of material to the other uses. For example raisin grapes are the only varieties canned, and the surplus raisin crop may also be diverted to the production of brandy for the fortification of wine. But when maximum yields occur in the same season in all the principal grape-growing areas, the situation becomes acute. There is less opportunity for diversion, the fresh market is clogged, and a chaotic condition develops. Methods of utilization should be developed that will provide an immediate outlet for surplus fresh fruit as well as for greatly augmented quantities of byproducts at canneries, drying fields, juice plants, and wineries.

Probably the largest items in the byproducts list are seeds, stems, and other raisin waste at the drying yards, and pomace, argols, and lees at juice plants and wineries. There are no statistics available on raisin waste. There is a probable annual production of grape pomace of about 185,000 tons. This includes skins, pulp, and seeds, potentially valuable for their content of tannin, pigments, odorous constituents, seed oil, and oil-free seed residue.

The argols and lees from juice plants and wineries are valuable for their content of tartrates, the crude material from which tartaric acid and its salts, including cream of tartar, Rochelle salts, and tartar emetic, are produced. It is estimated by the trade that about 30 percent of the tartaric acid in the United States is used for the manufacture of baking powder.

Importations from wine-producing countries in 1936, an average year, were 16.8 million pounds of argols, tartar, and wine lees, either crude or partly refined. These crude materials, valued at almost a million dollars, were admitted duty-free, because they contained less than 90 percent of potassium bitartrate. It would seem that if economically feasible methods for recovery of crude tartrates could be developed, at least a small part of this import trade could be diverted to domestic channels. In addition, in years of maximum production, it should be possible to stabilize the market by diversion of large quantities of surplus fruit to plants where the crude tartrates and other constituents of commercial value could be extracted and stored for gradual liberation in trade channels. This plan, founded on Federal research and developed over a period of years by cooperative organizations, has proved to be the salvation of the domestic lemon industry.

PRESENT RESEARCH

Considerable research is being done at present, most of it directed along the line of food and beverage uses. Problems under study include:

1. Methods of preparing grapes for shipment and storage as well as studies on spoilage control.
2. Methods for the preparation and preservation of grape juice.
3. Production and preservation of the various types of wine.
4. The production of raisin sirups.
5. The production of raisin-seed oil.
6. The disposition of winery refuse and distillery slops.
7. Methods for the economical manufacture of tartrates.

SUGGESTED RESEARCH

Suggestions for research on grape products and byproducts indicate that producers and processors are aware of the possibilities for industrial utilization and will welcome suggestions for improvements.

The research suggestions fall into the following general groups:

1. Develop methods for rapid determination of maturity and the effect of maturity on storage and general utilization.
2. Study the composition and differences of grape varieties.
3. Study the vitamins in the various grape products and develop methods for their preservation.
4. Investigate the drying of winery waste for stock feed.
5. Study the gel properties of grape varieties and investigate the possibilities of pectin extraction.
6. Investigate the odors of grapes and develop methods for their use in perfumes and confections.
7. Study the development, constitution, and extraction of grape pigments.
8. Develop uses for raisin-seed oil, with special reference to the cosmetic industry. About 15 percent of the weight of the seed is oil. Part of it is now used for spraying raisins, before packaging, to prevent sticking together.
9. Develop new uses and methods of extraction of tannin from grape seeds, skins, and stems.
10. Study the recovery of oil from grape pomace.
11. Develop methods for the economical handling of wine distillery sludge and the recovery of the tartrates as calcium tartrate or high-grade lees.
12. Study the products of destructive distillation of the pomace and seed press cake.
13. Investigate the utilization of the press cake after oil extraction from the seeds.
14. Develop uses for grapevine trimmings.
15. Make fundamental studies on the constituents of winery and grape waste material, with special reference to the oil and protein of the seed.

BERRIES

Berries in the aggregate represent an annual cash income to American farmers of nearly 50 million dollars.

Strawberries, the most important item commercially, have occupied an area of about 175,000 acres in recent years. The chief producing State is Louisiana, which has turned out annually over a million crates (24 quarts) in recent years. Other leading strawberry States include Florida, North Carolina, Virginia, and Maryland in the East; Arkansas, Tennessee, and Michigan of the Central States; and the three Pacific Coast States, California, Oregon, and Washington. The total crop annually amounts to about 11.5 million crates and yields the growers a cash income of from 25 to 35 million dollars. In some recent years strawberries unharvested on account of market conditions have been estimated as high as 300,000 crates. The Pacific Northwest packs about 75 percent of the canned strawberries and 65 percent of the frozen berries.

Cranberries, next in importance to strawberries, are grown on an area of about 27,000 acres. The total crop annually amounts to about

600,000 barrels, of which Massachusetts produces more than half. The other cranberry-growing States are New Jersey, Wisconsin, Washington, and Oregon. This crop annually amounts, in cash income to growers, to about 6 to 7 million dollars. Canning of cranberries, and canning and bottling of cranberry juice and cocktail are new and growing industries.

The bulk of raspberry production for processing is in four States, New York and Michigan in the East, and Oregon and Washington in the West, the two Eastern States packing a little more than 50 percent of the canned berries. The frozen-raspberry pack in the Pacific Northwest exceeded 9 million pounds in both 1936 and 1937.

The growing of loganberries is practically limited to the Pacific Northwest, principally the Willamette Valley of Oregon and the Puget Sound district in Washington. The average pack of canned loganberries is about 200,000 cases. In 1937, the frozen pack was over 2.3 million pounds.

Blackberries are grown, in general, farther south than raspberries. The principal areas of eastern production reach from northeastern Texas up through the Ohio Valley. Oregon and Washington pack more than 80 percent of the canned blackberries, and in addition froze over 6 million pounds in 1937.

The few thousand acres of currants in the country are located mostly in the lower Hudson Valley and on the shores of the Great Lakes.

The United States is the most important producer of strawberries and raspberries in the world, growing over 90 percent of the world's strawberries. England produces the bulk of the world's gooseberries and currants.

Berries occupy a rather unique place in the field of fruits. They are characterized by their fragile and for the most part highly perishable nature. As fresh fruit, they must be harvested and consumed within narrow time limits to prevent excessive losses or deterioration. Various food products and canned specialties prepared from berries are highly prized by the consumer.

In 1937 the total pack of canned berries was 1,854,729 cases, all sizes, or approximately 3 percent of the total pack of canned fruit. The frozen pack of berries totaled 63,343,776 pounds, or 56.8 percent of the total pack of frozen fruit. The great bulk of the frozen pack of berries is used in the jam, preserve, and jelly industries. The ice cream industry also uses large quantities of frozen berries. Statistical data on berry juices are not available.

Waste from the sorting tables in canneries and freezing plants, together with pomace from jelly and juice manufacture, bids fair to develop into a real problem of disposal. Remunerative outlets for this type of waste should be sought, possibly in the extraction of odors, flavors, and pigments, or in chemical treatment or controlled fermentation to produce rare sugars, acids, alcohols, etc.

PRESENT RESEARCH

Research now being carried on by various agencies in the United States is largely directed toward studies of different factors affecting the quality of fresh products and the preparation of canned products, juices, wines, jellies, preserves, flavors, and other products. The following specific lines of investigation are in progress.

Fresh fruit.

1. Breeding for improved quality of fruit and for disease resistance.
2. Testing investigations to determine the suitability of different strains and varieties for fresh shipment and for preservation by canning, freezing, or other processing.
3. Relation of fertilizers and soil fertility factors to strawberry growing in the Southeast. Closely related to this is a study of the effect of the application of certain minerals upon the shipping qualities of strawberries.
4. Irrigation of berries in the humid region.
5. Study of methods for combating diseases and insect pests.
6. Storage of cranberries, designed to lengthen the distributing season.
7. Nutritive value and composition of cranberries.
8. Preservation by freezing.

Processed fruits, byproducts, and wastes.

9. Studies on the canning of berries.
10. Simplification of jelly and preserve manufacture from berries and improvement of the uniformity of the product.
11. The preparation of frozen, preserved, and juice products from surpluses and culls.
12. Production of berry wines of uniform and improved quality and the study of spoilage organisms and methods to prevent their activity.
13. Factors affecting the quality of strawberry juice and the development of a practical method for preparing strawberry juice and strawberry concentrate.
14. Manufacture and preservation of cranberry products, including the composition and suitability of culls and damaged fruit for manufacturing purposes. The preparation of cranberry jelly, elimination of pectin and other precipitates from the juice and sirup, and the prevention of deterioration in preserved cranberries are the principal objectives.
15. A study of the effect of variety, storage, environmental factors, and methods of manufacture on the nutritive value and ascorbic acid content of currants.
16. Development of new and improved natural flavors and preparation of new flavor concentrates.
17. Manufacture of commercial products from blueberries.
18. Investigation of the wax-like coating of cranberries.
19. Utilization of waste in packing berries.

SUGGESTED RESEARCH

The highly perishable nature of most berries greatly limits their extensive distribution in the fresh condition or in forms which satisfy critical consumer demands. Therefore, an intensive program of research designed to improve the quality and stability of the fresh fruit is of considerable importance. The development and improvement of new food or nonfood products, byproducts, and specialties are also highly desirable to increase the value of the crops and to minimize surpluses and wastes.

The many different varieties of berries grown offer practically unlimited possibilities along the several lines of investigation which have been suggested.

Fresh fruit.

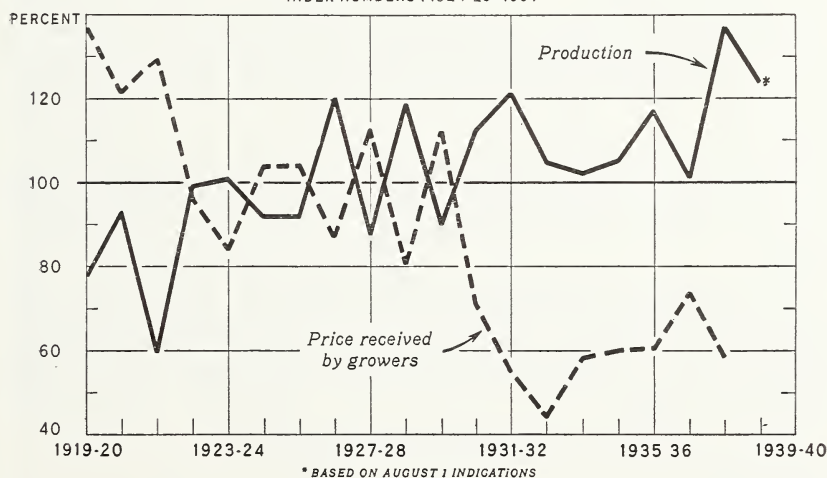
1. Inheritance studies of berries.
2. Fertilizer requirements and effects of varying fertilizer treatment on yield and quality of berries.
3. A study of the effect of variety, soil, and other factors on the suitability of berries for fruit concentrates.
4. The preservation of berries by freezing and storage to lengthen the distributing season.
5. A fundamental study of the composition, including separation and nature of pigments, studies on vitamins, and the nutritive value of berries.
6. Fundamental research on the identification of the odoriferous constituents of natural berry flavors.

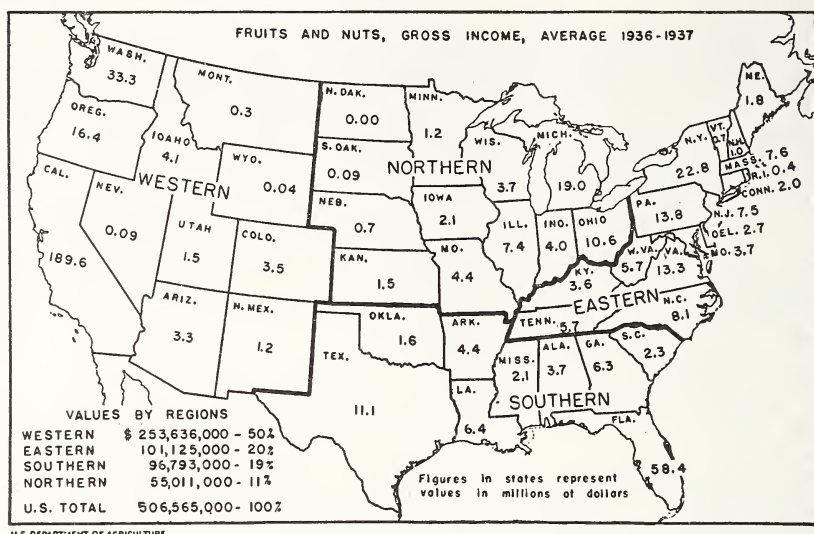
Processing, byproducts, and wastes.

7. Factors affecting the quality of strawberry and other juices.
8. The nutritive value and methods of manufacture of currant products.
9. New materials of construction for use in the concentration of berry juices.
10. Extraction of pectin and fundamental studies on the nature of the pectin so obtained.
11. Preparation of new or improved commercial products to increase the value of berries and to take care of surpluses. Preparation of sirups and toppings, juices, wines, jellies, preserves, and concentrates.
12. Microbiological studies on berry waste. Production of higher alcohols, ketones, and organic acids by controlled fermentation.
13. Utilization of cannery waste and disposition of liquid effluents from canneries. These constitute serious problems and should be given immediate attention in order to increase efficiency and prevent pollution of streams.

ALL FRUITS: PRODUCTION AND PRICE IN THE UNITED STATES, 1919-38

INDEX NUMBERS (1924-29=100)





MELONS

The principal types of melons produced in the United States are watermelons and muskmelons (cantaloup, honeydew, honeyball, Persian, and casaba), their commercial importance being approximately in the order named. Watermelons and cantaloups are grown commercially throughout the country, with the exception of a few States. Production of the others is confined largely to California, though considerable quantities of honeydew melons are produced also in Colorado.

The average annual commercial production of watermelons in the 5-year period ending in 1929 was about 61 million, and its value ranged from 10 to 13 million dollars. During the past 5 years, the production averaged about the same but the farm value was lower, ranging from 5 to 8 million dollars.

In some years many watermelons are left in the field because of adverse market conditions. The number not harvested was approximately 8,663,000 (13.6 percent of the total crop) in 1932; 1,354,000 (2.4 percent of the crop) in 1933; and 2,737,000 (4 percent of the crop) in 1935.

The commercial production of cantaloups and other muskmelons averages about 13 million crates a year. For the 5-year period ending in 1929 the farm value of these melons averaged 21 million dollars annually. The value in 1937, the highest since 1931, was 16 million dollars.

As in the case of watermelons, large quantities of cantaloups and other muskmelons are sometimes left in the field because of unfavorable market conditions. The muskmelons not harvested amounted to approximately 3,102,000 crates (19 percent of the entire crop) in 1932; 863,000 (6.7 percent of the crop) in 1933; and 410,000 (3 percent of the crop) in 1936.

PRESENT RESEARCH

Watermelons.

Watermelons are raised exclusively for shipment to the fresh-fruit market. The rind of surplus watermelons may be brined for use in

sweet pickles, but pickling varieties with thick rinds are grown especially for this purpose. This is a specialty product and the market is easily overstocked. Some surplus is also used as stock feed, and unharvested watermelons may be ploughed under. Many tons of watermelons are used for seed, which leaves the producer with great quantities of waste, most of which is now a total loss.

This survey has revealed that little active research on watermelons is in progress, and few specific suggestions for research were obtained. The principal research on watermelons is devoted to the following:

1. Processing or canning the juice.
2. Analysis of the seeds and study of the composition of the seed oil.

Muskmelons.

Cantaloups and other muskmelons also are raised entirely for the fresh-fruit market, and at present the only outlet for surplus and culis is as stock feed or fertilizer. Twenty percent of the market melons are wasted in normal years. In Colorado alone, an average of a million pounds of cantaloups are harvested each year for seed. The accumulation of waste at the seed farms constitutes an acute disposal problem.

The main object of research on muskmelons at present is—

1. Development of methods for drying muskmelons for cattle feed. Much more work is needed on this project.

SUGGESTED RESEARCH

Watermelons.

Fundamental knowledge is needed on the nature and quantity of the constituents of watermelons in order to prepare marketable products from watermelon waste. To obtain this knowledge the research listed below will be necessary:

1. Chemical analyses of fruit of different varieties at different stages of maturity.
2. Studies of the vitamin content of different varieties at different stages of maturity.
3. Development of methods for drying the waste for storage and subsequent industrial utilization.
4. Studies to determine the physical and chemical composition of the seed oil and develop new uses for the oil and its derivatives.
5. Fundamental research on the protein of the seed.

Muskmelons.

Before nonfood uses for muskmelons can be developed, careful analytical study will be needed to reveal what recoverable substances are present. The following research is suggested:

1. Studies to determine the chemical composition of different varieties at different stages of maturity.
2. An investigation of the vitamin and enzyme content and development of methods for their recovery as concentrated substances.
3. Studies designed to improve methods for drying and storing waste for use as feed and for industrial utilization.
4. A study to determine the physical and chemical characteristics of the protein of the seed.
5. Studies of the physical and chemical composition of the seed oil, as well as possible derivatives.
6. Microbiological studies of the waste with the object of obtaining higher alcohols, ketones, and organic acids.

VEGETABLES

In response to the trend toward inclusion in the diet of a larger proportion and a greater variety of vegetables, the total acreage of truck crops has trebled since 1920. There has been an increase in the growing of fresh vegetables for market, and also in those grown for canning or manufacture. The large areas of increased production have been in the South, in California, and in the sections adjacent to the large eastern cities.

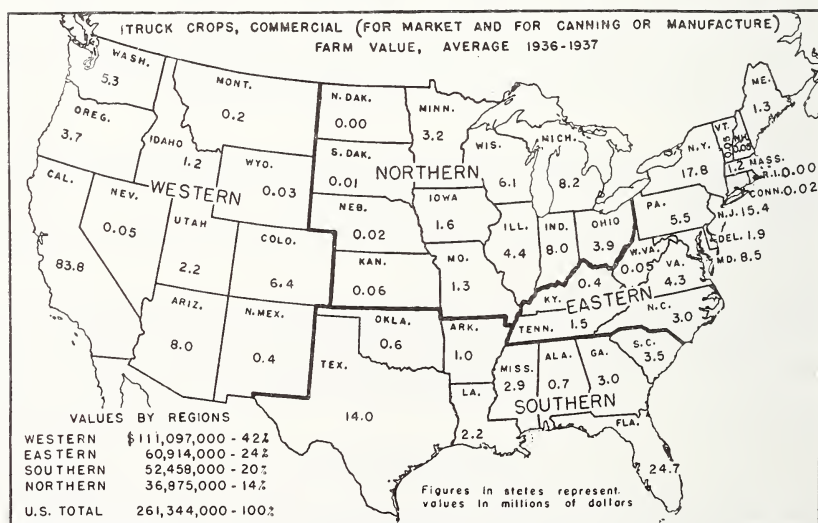
Notwithstanding the large increase in production, the income to the farmer from these truck crops has not increased. The truck growers were receiving a total income of about 250 million dollars 12 years ago, and about that same amount for twice the quantity of crops during the last 5 years.

The leading State in production of commercial truck crops is California, with more than half a million acres. Texas ranks next with about half that acreage, and other important States are Indiana, Wisconsin, Maryland, New York, Florida, and New Jersey.

An idea of the area devoted to the more important vegetable crops and the cash return to the farmer may be gained from table 9 and the following map.

TABLE 9.—*Acreage and farm value of commercial truck crops, 1920-37*

Year	Acreage			Farm value		
	For market	For processing	Total	For market	For processing	Total
	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>1,000 dollars</i>	<i>1,000 dollars</i>	<i>1,000 dollars</i>
1920.....	614,900	726,200	1,341,100	123,928	51,266	175,194
1925.....	966,770	1,166,170	2,132,940	192,250	71,086	263,336
1930.....	1,439,970	1,378,510	2,818,480	203,777	71,240	275,017
1935.....	1,603,600	1,456,850	3,060,450	175,200	55,681	230,881
1937.....	1,654,720	1,530,080	3,184,800	206,629	68,285	274,914



Surplus of market vegetables and carry-over of canned goods have combined to depress prices in recent seasons. In spite of a 25-percent reduction in acreage of sweet corn for canning in 1938, a good crop resulted in a pack of about 19½ million cases, a figure which has been exceeded only twice in the last 12 years (in 1935 and 1937). A record high production of both lima beans and beets for canning has disturbed the market for those crops. Increased demand for lima beans for freezing has greatly expanded the acreage planted, especially in New Jersey, Delaware, and Virginia.

In fact, the quick-freezing industry is opening a new field for the year-round retail distribution of vegetables. The Western Canner and Packer (April 1938) estimates the United States frozen vegetable pack for 1937 as follows:

	Pounds		Pounds
Asparagus.....	6, 254, 474	Peas and carrots.....	162, 808
Green beans.....	6, 870, 054	Spinach.....	4, 332, 659
Wax beans.....	434, 141	Squash.....	407, 087
Lima beans.....	17, 994, 571	Miscellaneous.....	50, 482
Broccoli.....	2, 094, 102		
Brussels sprouts.....	238, 780	Total.....	69, 717, 947
Carrots.....	331, 703		
Cauliflower.....	282, 415		
Corn, cut.....	4, 066, 655		
Peas.....	26, 198, 016	Corn on cob.....	556, 603

Even more spectacular than the rise of frozen vegetables is the development of the tomato-juice industry. In 1929 there was a commercial pack of 185,000 cases, and in 1937 the pack was 13,445,000 cases. This represents a seventyfold increase in less than 10 years.

The leading canned vegetables are tomatoes, corn, and peas. More than one-third of the frozen vegetable pack is green peas. Green lima beans, a minor canning crop, rank second.

Data on production and farm value of vegetables grown for both fresh-market sale and processing are given in table 10.

TABLE 10.—*Production and farm value of commercial vegetable crops,¹ 5-year average, 1933-37*

Vegetable	Production		Farm value	
	For market ²	For manufacture	For market	For manufacture
	<i>Tons</i>	<i>Tons</i>	<i>100 dollars</i>	<i>100 dollars</i>
Asparagus.....	67, 344	³ 54, 248	7, 859	3, 896
Beans, lima, shelled.....	5, 176	16, 876	845	1, 039
Beans, snap.....	188, 745	77, 980	13, 102	3, 408
Beets.....	47, 632	41, 500	894	462
Cabbage.....	961, 860	137, 760	14, 444	1, 172
Corn, sweet.....		662, 330	1, 354	6, 534
Cucumbers.....	77, 616	131, 808	3, 290	2, 940
Peas, green (shelled basis).....	51, 570	204, 662	10, 070	10, 331
Peppers, green.....	51, 000		2, 697	
Peppers, pimiento.....		14, 702		448
Spinach.....	110, 718	51, 760	5, 033	668
Tomatoes.....	526, 226	1, 610, 660	24, 243	19, 693

¹ Includes only crops used for fresh market, canning, or other processing.

² Does not include that portion of the crop not harvested because of market conditions.

³ California only. The California pack decreased from 92.1 percent of the total United States pack in 1933 to 75.87 percent in 1937.

The dehydration of vegetables is a minor industry, and most of the dried product is exported.

All vegetables are grown primarily for food use, and under this general category approximately 40 different products are of economic significance. Although vegetable crops are grown in every State, certain land areas are particularly suited to the growth of specific vegetables. These naturally become centers of production, which results in localized surpluses under certain economic conditions. In certain years tremendous tonnages of surplus material cause a slump in the food market, and some method of handling this material should be developed. One way to accomplish this would be to divert such surplus products to industrial uses.

Examples of such specialization are the production of winter and very early vegetables in Florida, Texas, and California for shipment to northern markets and the growing of peas in Wisconsin, where approximately 30 percent of the Nation's canned peas are packed.

In the handling of vegetable crops, there are large tonnages of discarded material that cannot go into food channels. Green leafy vegetables must be trimmed and the cull products segregated before shipment to the fresh-vegetable market; root vegetables must be trimmed or topped and the cull material sorted out; and cannery crops must be vined and hulled or sorted and trimmed before processing. In general, the commercial handling of these commodities requires packing or processing at central plants, and as a result considerable tonnages of waste, such as trimmings and low-grade, off-standard, and cull materials, accumulate at these central points. This is an important factor when concentration of raw materials and availability for industrial utilization is considered.

Many companies find themselves in the position of having to pay out large sums of money to get rid of the waste material in order to prevent it from becoming a public nuisance. This is especially true of salad crops, such as lettuce, celery, and new cabbage.

By reason of this necessary sorting and trimming often as much as 50 percent of the total crop produced on the land is relegated to a nonfood status and becomes a product of low value or even a liability. It is on this phase of the vegetable-crop problem that the regional laboratories should concentrate considerable effort. If this waste material could be returned to the farm in the form of feed or fertilizer, or could be made to yield derivatives of some value, part of the cost of production and handling of the food portion of the crop would be absorbed, or a new source of profit might be developed by diversion to nonfood uses.

The need for a definitely formulated program for intensive research in the utilization of surplus, culls, and waste from truck crops is emphasized by the tremendous quantities of material available and the limited amount of research now under way.

At receiving centers in the producing district, where fresh vegetables are packed or crated for shipment, vast quantities of trimmings from the leafy vegetables and of tops from root vegetables accumulate and must be disposed of. Although some of this material may be returned to the farm for fresh feed or for ensiling, by far the greater part of it must be carted away, dumped, or burned, and the cost of disposal becomes a part of the handling charge. No estimate of the total amount of this material, either as a whole or as concentrated in

various centers, is available. However, as an example of the condition facing all truck growers, it is estimated that the cost of disposal of waste and surplus lettuce alone in the Salinas Valley of California is about \$20,000 a year.

In estimating the amount of trimmings and waste available at processing plants, there is a tangible basis from which to work, since the packer knows his tonnage of raw material and his pack of finished goods. From such data it is estimated that of the corn, pea, and tomato crops moved to processing plants more than 2 million tons is nonfood material. This phase of the truck problem is discussed more fully under Processing Wastes.

PRESENT RESEARCH

Since vegetables are grown primarily for food, it is natural that most of the research on vegetable crops should deal with food problems. Comparatively little work is under way on the industrial utilization of the cull and surplus material. The present research on the dehydration of surplus vegetables and the concentration of tomatoes for soup stock seems to offer some promise, but even these types of work are directed primarily to utilization as food. Considerable work is being done on the treatment of cannery effluents and food-plant wastes. These are being considered largely from the standpoint of the abatement of a nuisance rather than of utilizing the end products, although some screened and precipitated material is being used as fertilizer. Present research, as carried on by producers, farm co-operatives, processors, and industrial, State, and Federal research organizations, may be summed up as follows:

1. Development of new or improved varieties, of better size, color, flavor, texture, or keeping quality, including development of new varieties especially adapted to preservation by canning, quick freezing, and other means.
2. Breeding of disease-resistant varieties.
3. Methods for control of diseases and insect pests.
4. Effect of soils and fertilizers on quantity and quality.
5. Nutritive value of fresh vegetables; effect of variety, soil, and fertilizers on nutritive value; effect of home cooking, canning, and commercial processing on nutritive value and vitamin content.
6. New and improved methods of processing by canning, freezing, juicing, pickling, etc.
7. Development of foods and feeds from processing wastes.
8. Development of nonfood uses either of vegetable constituents or of products found in their wastes.
9. Treatment of cannery effluents from the point of view of abatement of a nuisance or of a health hazard.

SUGGESTED RESEARCH

That both agriculture and industry are thinking along the lines of industrial utilization of agricultural products and reaching out toward an integration of food and industrial uses is indicated by many of the suggestions for research received from agricultural experiment stations and from industries that are either present or potential users of agri-

cultural products. The main lines of suggested research on truck crops are as follows:

1. A census of the constituents of vegetables should be made. This should include the organic and inorganic components, and should have as an objective the evaluation of the nutritive qualities of the products which may serve as a basis for application in industry.

2. These studies should include evaluation of trace elements found in vegetables and their possible role in nutrition and in the growth of the plant itself. It is known that the presence of certain trace elements in the soil displays a marked control over certain diseases of plants. Application of such knowledge may provide control of plant diseases or bring about an increase in yield per acre.

3. There is a generally growing feeling that vegetables, especially those produced primarily for processing, should not be produced solely on the basis of yield but also on a quality basis. The quality should be based upon the nutritive value as measured in terms of mineral and vitamin content.

4. It is believed that work should be done to increase mineral content and nutritive value of vegetables by natural means, such as selection and fertilization, and to preserve these qualities by improved methods of storage, freezing, canning, and dehydration.

5. Particular emphasis should be placed on the biochemical changes taking place during storage with a view to better control of the enzyme and chemical reactions. These studies should include methods for the preservation of vitamins in fresh and processed vegetables. A better understanding of their role in nutrition should be gained from these studies.

6. Work should be done on the preparation of vegetable concentrates for use in the food industry or as a means of preservation of the products until such time as they could be used in industrial processes.

7. Too little is known about the specific nature and reactions of the enzymes occurring in vegetables. Studies should be made of their role during growth and their influence during storage of vegetables. The oxidizing enzymes cause a great deal of trouble in food processing, and better methods of control of darkening and of oxidized flavors should be developed. Studies should also be made on the possible extraction of vegetable enzymes and their application in industrial processes.

8. Some work should be done on the possible use of starchy vegetables as sources of starch, flour, and adhesives. Certain plants might yield materials with very specific characteristics which would make them useful in industry. This is being considered in greater detail in the section on Root Crops.

9. Some vegetables contain considerable protein, which might find a place in the field of plastics.

10. Methods for utilization of waste and surplus vegetable material and methods of storage of such material for future processing should be developed.

11. Fundamental studies should be conducted on the components of vegetable material in order that more may be known about their physical properties, solubilities, chemical reactions, and stability. This information would form the basis upon which industrial chemists might build up applications or develop new synthetic products.

PICKLING CROPS

Almost any fruit or vegetable with flesh sufficiently firm to withstand brining or to serve as a carrier for spiced sirup may be pickled. Cucumbers and cabbage, however, are the only crops grown specifically for the pickling industry. The pickle and sauerkraut industries are fairly widely distributed. Two-thirds of the acreage devoted to cucumbers is used for cucumbers for pickling. Only about 10 percent of the cabbage crop is used for sauerkraut.

The cucumber crop is marketed as fresh cucumbers, cucumbers for pickles, and cucumbers for seed. The total value of this crop is nearly \$12,000,000 annually. Of the total 1937 crop of 11,698,000 bushels, 7,949,000 bushels were processed into cucumber pickles. This crop is grown fairly uniformly over the country. The South leads in the production of fresh cucumbers for the very early market, and the North leads in their production for pickling. Formerly, pickles were produced almost entirely in the Northern States. Within the last few years, however, there has been a shift in the areas producing pickling cucumbers. This has been influenced somewhat by the Federal-State cooperative research program on the pickling of cucumbers under southern conditions. Michigan and Wisconsin still lead in the production of pickling cucumbers. In the average production for the 10-year period 1927-36, North Carolina and Texas ranked 9 and 17 in the list of producing States, but in 1937 they ranked 5 and 9.

Some of the surplus of market cucumbers can be used as salt stock for pickles, and in this way the material may be held for as long as 2 years. All the surplus, however, cannot be handled by the salting plants, and some methods should be developed for making use of this material.

One of the most pressing needs is for research work on the utilization of seed-plant refuse, that is, the material discarded after the seeds are removed. About 3,000,000 pounds of cucumbers are harvested for seed each year in Colorado, where most of the commercial cucumber seed is grown. At present, feeding the fresh material to stock is about the only method of utilization. The rest of the material must be disposed of so that it will not become a nuisance.

The total cabbage crop for the 5-year period 1933-37 averaged 1,138,920 tons. Of this huge crop, about a million tons went to the fresh market, 12 percent went to sauerkraut manufacturers, and 3.4 percent, or an average of 39,000 tons per year, was left in the field because of unfavorable market conditions.

The sauerkraut and sauerkraut juice packed in 1935, according to the Census of Manufacturers, is shown in table 11.

TABLE 11.—Quantity and value of sauerkraut and sauerkraut juice packed in 1935

Product	Quantity	Value
Sauerkraut:	<i>Cases (all sizes)</i>	<i>Dollars</i>
Bulk.....		2, 006, 668
Canned.....	4, 404, 974	5, 818, 078
Sauerkraut juice, canned.....	119, 681	162, 449
Total.....	4, 524, 655	7, 987, 195

There is an average loss of 15 percent in trimmings at the sauerkraut plant. This means an annual accumulation of close to 21,000 tons of highly perishable waste. In addition, each year there is the trimming waste from a million tons of market cabbage, which accumulates at the packing sheds, and from 5,000 to 110,000 tons of cabbages left unharvested in the fields.

The sauerkraut-juice pack of almost 120,000 cases indicates that some attempt has been made to salvage the excess liquor from the fermentation vats. At least a small part of the fresh trimmings are undoubtedly utilized as stock feed, but according to reports made to the survey workers, no studies on the utilization of the large accumulations of cabbage waste are in progress or are contemplated, although the disposal of this waste is an expense to growers or processors.

PRESENT RESEARCH

Cucumbers.

At present very little research is being conducted on the nonfood utilization of cucumbers or their byproducts. The research now in progress is devoted to production and to improvement in pickling methods. The main projects are:

1. Development of improved strains.
2. Studies of factors influencing the yield, grade, and shape of pickling cucumbers.
3. Studies designed to reduce nubbins in commercial plantings.
4. Studies in fermentation microbiology, including all factors having any influence on rate, quality, and control of manufacturing processes.

Cabbage.

The following research on cabbage and sauerkraut is now in progress:

1. A study of genetic factors involved in the production of superior strains or varieties of cabbage.
2. Investigation of the effect of soil type on chemical composition of cabbage and hence on fermentation of sauerkraut.
3. A study of the relation of environmental factors to the rate of fermentation and the quality of the sauerkraut produced.
4. Studies on the vitamin C content of sauerkraut and sauerkraut juice.

SUGGESTED RESEARCH

Cucumbers.

No specific suggestions for further research on cucumbers were made to the survey group, but it is felt that certain phases of the present research should be continued. The following research projects are suggested:

1. Fundamental studies on the salt tolerance of enzymes active in the pickling process and their relation to quality.
2. Development of methods for the recovery of organic materials in solution in waste brine liquor, and determination of what is available for further use. Salt used may also be recovered for cattle.
3. Investigation of methods for salvaging cucumber waste at seed plants. The natural constituents of this fresh waste are undoubtedly quite different from the dissolved materials in processing wastes.

Cabbage.

No definite problems in connection with the manufacture of sauerkraut or the disposal of sauerkraut waste have been suggested. Disposal of the waste is discussed in the section on Processing Wastes.

EDIBLE TREE NUTS

Nut crops are grown commercially in the Southern States and on the Pacific coast.

Cultivation of nuts as a commercial crop began on the Pacific coast with the introduction of almonds and English (Persian) walnuts into California by Spanish settlers. At present, 98 percent of American almonds are grown in California. There have been extensive plantings of walnuts in Oregon in the last 40 years, and commercial plantings of filberts in the Pacific Northwest are even more recent. Pecans are native to the Southern States. Improved varieties have been developed by selection and propagated by budding. Of native nuts not domesticated, black walnuts from the Eastern States and piñon nuts from the Southwest have an established place in retail markets.

In recent years from 10,000 to 14,000 tons of almonds have been produced annually, with a farm value of 2 to 4 million dollars. Walnut production in California in recent years has ranged from 30,000 to 50,000 tons annually. The output of improved and seedling pecans has ranged from 20,000 to 50,000 tons. Filberts are grown chiefly in Oregon and Washington. The Oregon output has increased from 60 tons in 1927 to 2,230 tons in 1937.

The total crop of tree nuts in 1938 is expected to amount to about 84,000 tons, which is slightly below average production. This crop includes 45,200 tons of English walnuts; 24,400 tons of pecans, of which 9,220 tons are improved varieties and 15,100 tons wild and seedling pecans; 12,100 tons of almonds; and 2,200 tons of filberts.

The production of tree nuts, with the possible exception of wild and seedling pecans, is expected to increase somewhat during the next few years.

Prices to growers for tree nuts fell to low levels in 1930 and 1931. Since then the prices of walnuts and improved pecans have declined somewhat further. Prices of wild and seedling pecans have remained low, on the average. Almond prices, on the other hand, were high in 1935 and 1936, and even in 1937 when there was a bumper crop they remained well above their depression lows.

Nuts are used primarily for food either directly or as constituents of pastry, candy, ice cream, or other such delicacies. Most of the research now in progress is directed toward the preparation of the nuts for marketing. There has been no extensive investigation of the economic use of nutshells. Very little is being done on the nonfood uses of the nut kernels.

While the varieties of nuts included in this report differ in some respects, they have enough in common to warrant treatment as a group.

PRESENT RESEARCH

The research in progress on nuts is limited and deals primarily with the preparation of the kernels for marketing. The survey showed that the following projects are in progress:

1. Studies of kernels to determine why some are not well developed and how this fault may be corrected.
2. Pathological studies on pecans.
3. The study of fumigants to provide adequate and economical protection against certain types of spoilage.
4. Experiments on the removal of walnut husks by the use of ethylene adapted to commercial conditions. These are proving to be of value in raising the grade of shelled nut meats.
5. Studies on the canning and storing of nut meats for protection against the development of rancidity or objectionable flavors.

SUGGESTED RESEARCH

The use of the nonedible portion of nuts and nonfood derivatives from nut meats appears to be possible. It will be necessary to have more fundamental knowledge of the kind and quantity of constituents in the various parts of the nuts before investigations along certain lines can be advanced. Certain other lines need not depend on such knowledge. Studies of both types suggested for investigation are:

1. Inheritance studies on nuts and attention to the causative factor responsible for the development of walnut kernels.
2. The development of a machine for the satisfactory shelling of walnuts.
3. Insect control in stored nuts.
4. Development of adequate methods for storage and canning to retard or inhibit development of rancidity.
5. The study of the vitamin content of nuts, and the extraction and possible concentration of such vitamins for commercial concentrates.
6. The determination of the chemical composition of different kinds of nuts at different stages of maturity.
7. Fundamental studies to determine the constituents of walnut husks.
8. Fundamental studies on pecan oil involving proper extraction, properties, constituents, and derivatives.
9. A study of the use of ground nutshells as a filler in certain rubber preparations and their possible use in making plastics and insulating materials.
10. The preparation of ground shells for abrasives, for use as a dusting agent for cleaning certain types of furs, as a carrier for certain insecticides, and as a diluent for certain insecticidal dusting powders.
11. The preparation of activated carbon from shells and fundamental studies of its adsorptive power.
12. A critical study of the lignin in nutshells.
13. The distillation of walnut shells and the study of the volatile and nonvolatile portions.

PROCESSING WASTES

Processing wastes may, for the purposes of this report, be defined as wastes resulting from the commercial packing or processing for market of food commodities such as nuts, fruits, vegetables, meat, milk, and poultry. Roughly, the classification is as follows:

I. Solid wastes:

A. Nonperishable:

1. Shells—walnut, filbert, and pecan.
2. Pits or kernels—apricot, peach, prune, olive, date, and cherry.
3. Seeds—apple, tomato, grape, citrus, melon, etc.

B. Perishable:

1. Irregular-shaped or low-grade culls.
2. Leafy and butt trimmings.
3. Fruit skins, cores, and trimmings.
4. Peel and rinds—melon, orange, lemon, grapefruit, etc.
5. Pomace from juice plants and wineries.
6. Stems, pods, vines, hulls, cobs, and husks.
7. Garbage, and its use as feed, as humus, or for recovery of fat.

II. Liquid wastes:

1. Wash waters carrying highly diluted soluble matter and finely divided particles in suspension.
2. Dissolved organic matter, such as sugars, soluble proteins, whey, and other milk solids.
3. Heavy sludges of material in suspension: Curd, fruit pulp, fermentation sludges, etc.
4. Fatty wastes, skimmings from butter, vegetable and fruit oils, plants, etc.

The economic significance of these widely distributed products becomes apparent when the variety of commodities which contributes to their accumulation and the tonnages involved are considered. Most of the significant sources, aside from marketable edible surpluses, are listed in the above classification as true wastes.

It will be noted that the solid wastes are arbitrarily divided into two general types, nonperishable and perishable. The handling or disposal of the perishable and liquid wastes has always been an acute industrial problem of national importance. Its solution is becoming particularly urgent since the enactment of recent State legislation, sponsored by national resource conservation associations, particularly the fish and game commissions. The acuteness of the problem has been increased because these recent laws prohibit pollution caused by dumping these wastes into streams. When large quantities of oxidizable materials are promiscuously dumped into streams, unsanitary conditions result, and fish and other aquatic life are injured. These waste materials deplete the oxygen content of the water and thus cause the death of aquatic life. Scientifically, the phenomenon is known as exerting a "biochemical oxygen demand" on the stream or body of water. This may be expressed as a measure of the oxidizable material added to a stream or remaining unoxidized at the particular point under examination, and constituting a draft on the oxygen resources of the stream below that point.

Legislative agencies, however, have made but little attempt to help those who cause the trouble to provide remedies. The solution has been left largely to the individual offenders, and in many cases no solution has been forthcoming. Many of these private enterprises are not staffed with scientific workers, nor are they financially able and equipped to carry out research along these lines. Research

on the general subject by State and Federal agencies has been largely on methods of detection of pollution by means of the "biochemical oxygen demand" and other tests.

These researches have not been concerned with the conservation of the waste materials for further industrial utilization except in a few cases. It has been urged that one of the major duties of the regional laboratories should be the initiation of research for the development of satisfactory economic methods for treating these materials. If waste materials are to be available for industrial utilization they must be stored over long periods of time. It must be borne in mind that the production of the commodities which contribute to the waste supply is seasonal and that the wastes accumulate during relatively short periods of time. This means that if they are to be used for industrial manufacturing purposes they must be so processed initially as to furnish the continuous source of supply necessary to support such use.

Probably the primary reasons for the apparent lack of interest in these wastes by economic groups or research organizations are their scattered distribution and highly perishable nature, together with the facts that many of them are low in content of obviously valuable constituents and are difficult to handle.

Federal, State, and industrial agencies have in the past conducted researches directed toward the development of waste-disposal methods of the general type in which the entire waste of a plant is "hogged" and disposed of through the sewer as a means of eliminating a public nuisance. These methods are all quick and effective ways to dispose of the waste but no return is obtained to assist in paying the cost of handling, and that cost must be considered as a total loss; furthermore, unless the sewage is treated, the problem of stream-pollution remains.

In many cases it is not so simple a matter to dispose of waste material. It is estimated that the cost of disposing of the waste lettuce and trimmings in one local western area is \$20,000 a year. This is an actual expenditure for the purpose of disposing of a nuisance. It is conceivable that with proper handling some use might be made of this material and the cash return might bear a part of the cost of processing. A few years ago, the disposal of the rag and peel from citrus canneries was an acute problem, but today nearly all of it is dehydrated for cattle feed at a profit to the processing plant and to the citrus cannery as well. The amount and character of such waste materials, the great need for disposal and utilization methods, and the possibilities of success in this field, emphasize the need for regional-laboratory research along this line.

PRESENT RESEARCH

When the magnitude of the field is considered, there is comparatively little research in progress which has as its objective the non-food utilization of the many thousands of tons of these wastes. The projects under way are primarily concerned with treatment of cannery effluents to prevent stream pollution, and with the processing of cannery waste to yield industrial products.

Treatment of cannery effluents.

1. Trickling filters.
2. Chlorination.

3. Settlings, followed by chlorination and the use of trickling filters.

4. Chemical precipitation and utilization of the precipitate as fertilizer.

Industrial byproducts.

5. Burning waste and collecting ash for fertilizer use.

6. Recovering of wax from fruit skins (apple and pear) for use in stencil sheets, waterproof coatings, etc.

7. Drying or ensiling refuse for utilization as stock feed.

8. Recovery and refining of fatty substances and oils and their utilization in manufacture of edible oils, cosmetics, and soaps.

SUGGESTED RESEARCH

Information obtained during the regional laboratory survey points to the fact that if materials such as these wastes are treated in a proper manner they may be capable of yielding a product, or in some cases a series of products, which would not only repay the cost of treatment and effectively dispose of the nuisance problem, but may even equal or surpass the value of the primary processed market commodity. Competition is now evident in some cases between products of the same origin; for example, fresh apples now compete with dried apples, canned apples, apple juice, and apple confection. Competition is so keen that, even when using the most economical and the most effective methods, it is difficult to make producing, harvesting, or processing operations profitable, and the producer or processor must utilize to the fullest extent every product which is handled in order to realize a reasonable return.

Most of the fresh fruits and vegetables sold in produce markets are packed at the shipping point to meet requirements of State and Federal grades. As a result of packing under these standards much of the fruit is culled, and vegetables must be carefully trimmed and packed. This results in the accumulation of wastes from almost every commodity raised for market, and makes the problem of waste utilization one which is common to nearly all food-packing or processing plants. Therefore, it is not surprising that the Department has been urged to give early consideration to research in this field.

The suggested projects on the waste problem fall into the following general groups: Feeds and foodstuffs, composts, industrial utilization, and nuisance waste disposal.

Feeds and foodstuffs.

Usually, the first thought in connection with any farm food waste is a consideration of its value as a feed for livestock. So long as such material as culls, tops, vines, and trimmings remains on the farm, its disposal is entirely a problem of good farm practice. When the crop moves to central receiving stations for sorting, trimming, and packing for the fresh market, or to canneries or other processing plants, these wastes accumulate with unbelievable rapidity and almost inconceivable quantity.

For instance, at one freezing plant in the Pacific Northwest, the day's output of frozen peas is 16 tons, and leaves a strikingly large amount of refuse from the viner. When it is considered that the average annual production of shelled peas for the 5-year period 1933-37

was 200,000 tons, it will be realized that the quantities of peavine waste accumulated in a year are enormous.

Peavines are splendid feed, either fresh, dried, or ensiled. Much of the material is hauled away by the farmers who make deliveries to the processing plants, but thousands of tons annually become a factor in the general cannery waste disposal problem. To this must be added lima bean vines, husk, cob, and silk from corn canneries, outer leaves and trimmings from sauerkraut plants, beet tops and asparagus butts, and other similar wastes. These are all palatable, nutritious, green feeds which should be salvaged to a much greater extent than is thought at the present time. To these must be added the skins, seeds, and trimmings from 1.6 million tons of cannery tomatoes.

Fruit wastes also constitute a great problem. Pits and peels, skins and cores, pomace and seeds all form natural cultural media for all sorts of spoilage organisms and breeding grounds for orchard pests. Much of this material is now salvaged for feeding purposes, more especially by dehydration, but attempts have been made to process specific products for special purposes, for example, the use of pimiento cannery waste in winter feeds for laying hens to prevent pale yolks when green range is not available.

Animal wastes could be used to a much greater extent as sources of protein and minerals in poultry and stock feeds. The larger plants have been forced to develop means of disposal of their wastes, but smaller local creameries, cheese factories, slaughterhouses, and egg-breaking plants, many of them cooperative organizations, should be assisted in finding profitable means of disposal for their wastes, preferably in some form that can be returned directly to the farmer as feed or fertilizer.

Eating food-crop wastes may sound like eating garbage, but this is distinctly a false impression. The American public last year probably drank 80 million gallons of canned fruit juices, not including apple cider, for which not even approximate figures are obtainable. In the beginning, most of the fruit juices were tried out as means of utilizing off-size, off-shape, but otherwise sound fruit culled out as unsalable for graded and packed fresh fruit. At the present time, while no one raises fruit for juice, this method of preserving culls and surplus has salvaged thousands of tons of fruit, and added a palatable and nutritive food to the American diet. Most of this has been a development of the last 10 years. As many as 125,000 tons of cull and surplus lemons have been processed in a single season for lemon oil, pectin, and citric acid, and the residues converted into animal feed. In California the average annual production of lemon oil is from 150,000 to 200,000 pounds. The annual production of orange oil in this State is over 100,000 pounds. These oils are produced from cull and surplus fruit.

There are infinite possibilities still locked within the hundreds of thousands of tons of so-called wastes from our food packing and processing plants, waiting the catalyzing action of trained minds in order to add color, flavor, variety, and increased nutritive value to our diet.

Suggestions toward this end that have been offered during the course of this survey may be summed up as follows:

1. Improvement of methods of preparing waste material for animal feed. This seems to offer a profitable outlet if methods can be devised

to preserve the nutritional quality of the feed, with regard to vitamin and mineral content. As examples, in one western State there are annually over 1,000,000 pounds of waste melons and over 3,000,000 pounds of waste cucumbers at plants specializing in the production of commercial seed. All of this material is available for use as feed.

2. Utilization of waste leafy vegetables as a source of chlorophyll and vitamin G. The pressed juice might become an enrichment medium for commercial cultivation of bacteria, yeasts, and molds, and the press cake become an ingredient in animal feeds.

3. Determination of the nutritional value of wastes and feeds prepared from them in order that something may be known regarding their use for livestock feeding.

4. Study of the preparation of vitamin concentrates from waste fruits and vegetables. A profitable market might be developed in the feeding of such products to poultry and fur-bearing animals.

5. Study of the preparation of vitamin concentrates from waste materials such as the excess yeast from breweries, distilleries, and wineries. A profitable market for such products might be developed in feeds for poultry and fur-bearing animals.

6. Improvement of methods for recovering milk solids from the wastes of creameries and cheese factories and for incorporating the recovered product in feeds. An effort should be made to use the wastes from the numerous small and isolated creameries with a minimum expenditure for new equipment. (See also the section on Milk Products, p. 284.)

Composts.

It is universally recognized that organic matter or humus is the most important component of the soil. In the ordinary processes of crop production, fertility is steadily being lost and must eventually be restored by fertilization and proper soil management. Long-term field experiments have definitely shown that the maintenance of an adequate supply of humus is the most effective means of maintaining soil fertility.

Little is being done in this country toward the utilization of the many wastes of agriculture suitable for the preparation of humus or artificial manures. Many European and other foreign countries, however, have made substantial progress along these lines and have recognized the value of these materials for composting. A substitute for the gradually vanishing supply of horse manure, hitherto considered indispensable, has, for example, been reported as suitable for use in mushroom culture. The possibilities for the use of artificial manures in many other agricultural enterprises, including home and professional gardening and greenhouse culture, lawns and golf greens, are almost without number.

Agricultural wastes suitable for composting comprise a very wide variety of materials. These include, among the processing wastes, stems, stalks, pods, vines, hulls, cobs, husks, leafy and butt trimmings, fruit cores, and others. For purposes of enrichment with respect to nitrogen or other constituents, it may be found highly advantageous also to utilize fish scrap, slaughterhouse refuse, bones, poultry litter, pressed cakes, animal manures, ashes, and inorganic mineral supplements, which may be added to the various composts in suitable proportions. Also, in this connection, a means may be found for a more

profitable disposal of garbage, tankage, and sewage sludge from cities or large centers of population.

Investigations suggested along these lines include the following:

7. Fundamental research on the response of the various wastes and mixtures to microbiological decomposition.

8. A determination of the optimum moisture, temperature, aeration, and other conditions for obtaining the most desirable humidified product with respect to physical and chemical properties.

9. The incorporation of the proper inorganic constituents to enhance or supplement the fertilizer value.

10. Essential investigations of the most practical and economical composting processes which will be applicable or readily adaptable to the operation of the particular establishments or industries producing the wastes to be used as raw materials.

(See also the material on composting in the section on Agricultural Wastes, p. 69.)

Industrial utilization.

A complete census of the chemical constituents of the important wastes is a first essential in the development of a program of utilization. Many wastes contain proteins, pectin, tannin, cellulose, sugars, oils, organic acids, waxes, enzymes, vitamins, odorous and flavorful constituents, pigments, and a wide variety of other complex organic compounds. An accurate knowledge of quantities and properties is much needed. When that information is available, methods of isolation and purification of the constituents should be worked out. The special properties of some of them may suggest immediately the fields in which they can be used profitably. For instance, oils extracted from kernels, pits, seeds, and shells may find use in human food, in cosmetics, in soapmaking, or in paints and varnishes. Enzymes from pineapples or papayas, asparagin from asparagus, and new perfumes and pharmaceuticals from unsuspected sources are other examples of possible products.

Numerous suggestions for this type of study have been received, and these may be listed as follows:

11. Work on methods of disposal of waste and surplus vegetable material, and on methods of storage of such material for subsequent processing. These are important items in such a research program since the material demands prompt handling in order to prevent spoilage, and the raw material is available only a few weeks a year. For this reason storage and drying costs and facilities must be taken into consideration.

12. Development of methods whereby recovery of proteins, pectin, tannin, cellulose, sugars, oils, and waxes and other constituents of waste materials from food-processing plants will be economically feasible.

13. Development of methods for the preparation of perfumes, extracts, flavors, pigments, and pharmaceuticals from waste fruit and vegetables.

14. Study of the recovery of such products as asparagin from asparagus, and the separation of glucosides from wastes.

15. Investigations on the extraction of enzymes from waste material, such as bromelin from pineapples and papain from papayas.

16. Study of the recovery and utilization of excess yeast from breweries, distilleries, and wineries.

17. Investigation of the possibilities of producing organic acids, alcohols, aldehydes, ketones, and similar products from waste material by the use of bacteria, yeasts, and molds. Many of the products essential to national defense may be produced from such material in time of an emergency.

18. Development of methods for the utilization of fiber material from waste products such as pea vines, asparagus, celery, grape vines, etc. Such products might easily become binders for asphalt materials, press-board, and mouldings.

19. The utilization of fibrous wastes in building materials, fiber-board and plastics, and the use of finely ground wastes as fillers or as carriers for insecticides should be studied further. (See also the section on Agricultural Wastes, in which this possibility is discussed at greater length.)

20. Development of methods for the extraction and utilization of the oil from waste material, and from kernels, pits, seeds, and shells.

21. Further investigation of the utilization of shells, pits, and seeds in the making of activated carbons, plastics, floorings, fillers, and carriers for insecticides.

22. Study of destructive distillation of cannery refuse, shells, pits, seeds, etc., especially for the production of activated carbon.

23. Development of methods for the recovery of milk solids from creameries, cheese plants, etc., and expansion of the use of such recovered material.

24. Expansion of the use of horns, hair, feathers, bones, etc.

25. Finding of uses for the wide variety of protein materials from packing-house wastes, creameries, and cheese plants. This material constitutes a major problem in itself, which is discussed in detail in the sections on animal products. Adhesives, binders, plastics, new synthetic fibers, and a wide range of other industrial products have been suggested as possible outlets for such wastes.

26. Fundamental chemical investigations to find ways by which waste material may be diverted to its most profitable use by reason of its content of certain constituents.

Nuisance waste disposal.

Perhaps the greatest single item in the waste problem is waste water-wash waters from fruit-packing houses, acid waters for removal of spray residues, lye waters from drying sheds and peeling tables, salt waters from pickling vats, blanch waters, Steffens waste from beet-sugar plants, and tremendous quantities of water from the daily or twice daily cleaning of canneries, freezing plants, dairy plants and cheese factories, slaughterhouses, and meat- and poultry-packing plants. This water is heavily charged with added chemicals, with organic materials in solution or in suspension. It also contains spoilage organisms of all types, and soil and sand carried in on the raw materials.

The immense quantities of water to be handled make it impractical to attempt to recover added chemicals or soluble organic materials by present methods. A steady increase in the number of States requiring nuisance abatement before a specified date makes this problem increasingly acute. While no definite suggestions for methods of attack have been received, there is insistent demand for economical and satisfactory disposal of such wastes, preferably by systems that

can be quickly and easily installed without disrupting present factory set-ups.

ROOT CROPS

The most important of the root crops, white potatoes and sweet potatoes, are discussed separately in this section. Tuber crops, such as artichokes, chicory, dahlia, dasheen, canna, and arrowroot are also included here. Since these commodities are essentially starch or carbohydrate crops, the general discussion of starch, fermentation, and motor fuels research under cereal crops should be read in conjunction with this section in order to gain the complete picture of current and suggested research on the tuber crops.

WHITE POTATOES

Potatoes comprise the largest vegetable crop in the United States. During the 10-year period from 1928 to 1937 the average yearly production was 371,844,000 bushels. In 1937 the total crop was 393 million bushels.

Commercial potato production is concentrated in a few well-known areas: Aroostook County, Maine; Long Island, N. Y.; Eastern Shore of Virginia; Red River Valley of Minnesota; and southern Idaho. There are also important growing areas in Michigan, Wisconsin, Colorado, Pennsylvania, the Carolinas, and elsewhere. In recent years, the growing of early potatoes has become increasingly important in the South.

The chief producing States for the late or main crop are Maine, with an average output recently of around 44 million bushels; New York, producing around 29 million bushels; Pennsylvania, with about 25 million bushels; followed by Michigan, Minnesota, Wisconsin, Idaho, and Colorado.

An idea of the crop division as between the early and late regions may be gained from the 1937 crop, which was fairly typical in point of distribution. In that year the total crop amounted to 393 million bushels, and of this quantity the late States produced 318 million bushels, the intermediate States 37 million bushels, and the early States of the South 38 million bushels.

The gross income to growers of potatoes in 1937 amounted to slightly under 239 million dollars, and in 1936 to some 276 million dollars.

A typical picture of utilization of the crops may be cited from the 1937 figures. The production that year amounted to 393 million bushels. Of this, about 32 million bushels were disposed of as unfit, waste, and feed for livestock; the quantity used as food on farms amounted to 64 million bushels; saved for seed, 32 million bushels; sold, 265 million bushels. The quantity sold in 1937 brought farmers an actual cash income of 198 million dollars, this particular year having been one of very low prices. The average price of potatoes received by farmers over the last 10 years has ranged between a high of \$1.32 per bushel in 1929 down to 39 cents per bushel in 1932. In 5 of the last 7 years, the average season price to growers has been below 60 cents per bushel. Last year (1937), for instance, it averaged 53 cents per bushel.

Potatoes are essentially a domestic crop. There is no international trade of significance. In recent years exports and imports have averaged around or under a million bushels each and have tended to cancel each other.

The consumption of potatoes is relatively inelastic. That is, under similar demand conditions, small crops usually result in larger returns to growers than do large crops. Since there is a considerable variation in yield per acre and in the total crop resulting from this factor, it frequently happens that although the acreage remains fairly stable, the crops and prices of given seasons vary greatly. An increase of only 2 to 4 percent above average production often seriously depresses prices.

To quite an extent the yield per acre is dependent upon weather conditions during the growing season, and the average has ranged during the past 10 years from 100 to 123 bushels per acre for the United States as a whole. When high yields occur the surplus of No. 1 potatoes is frequently sufficiently high to greatly depress the market price. About 10 percent of the crop is culls, and the loss from diseased and frozen potatoes and shrinkage in storage may also amount to as much as 10 percent of the total crop. Because of these conditions, which necessarily prevail in the potato-growing industry, there is a definite demand for a profitable means of utilizing, for other than direct food use, the annual supply of cull and second-grade potatoes and also of excess first-grade potatoes during years in which large surpluses occur.

PRESENT RESEARCH

Potato research work is directed largely to studies on various production factors and the influence of these factors on the quality of the crop for food uses. The research of Federal and State agencies has been confined largely to studies on the effect of cultural, varietal, and environmental influences on crop yield and quality, looking to increased production and the general improvement of the potato for consumption as food. Such studies are obviously of great importance both to the producer and consumer. Considerable research on improved methods of storage and handling, the causes of deterioration, consumer preferences, and marketing of potatoes is being done. Much less attention has been given to investigations on using potatoes as a source of starch for industrial and other purposes. The present potato research in the United States may be conveniently classified as follows:

1. Development of disease- and insect-resistant varieties, varieties resistant to drought and heat, varieties having desirable qualities for food purposes, and varieties adapted to the growing season in various sections of the United States.

2. Determination of the effect of various types of long and short rotations, and the use of winter cover crops with continuous production.

3. Investigations in field-plot technique, depth of planting, variety trials, spacing, twin rows, date of planting, size of seed piece, cultivation, irrigation, and root development.

4. Important studies on rates of application; placement; kinds of fertilizers, including a great deal of minor elements work; and on rapid tests for deficiencies in fertilizers.

5. Studies of effects of climatic and soil factors, fertilizers, fumigants, insecticides, and their internal and external influences, on growth of vines and set of seeds and on number, size, culinary quality, chemical composition, and starch content of tubers.

6. Studies on the nature of fungus, bacterial and virus diseases, and on the various insect pests—their control or eradication.

7. Some studies on improved methods for reducing losses of potatoes in storage and for reducing injury in handling; on potato storage diseases, and on the causes of deterioration during storage.

8. Economic investigations on the marketing quality of potatoes, the factors which influence customer preferences, buying practices, price, and demand, as well as studies on the cost of potato production in various localities.

9. Studies on the variation in the cooking and eating quality of potatoes; and on the effect of various cultural, varietal, and environmental factors on potato yields and quality. These studies are being correlated with the composition and physical structure of the potato with the object of improving its quality for food use.

10. Investigations on the vitamins present in potatoes and on the comparison of the vitamin C content of immature, mature, and stored tubers.

11. Some research on potato-starch production with the object of improving its quality. The uses of potato starch for textile sizing and paper sizing and for alcohol manufacture are also being investigated.

12. Investigations have been conducted on the use of cull potatoes in ensilage and other feeds. In connection with this work some dehydration studies were conducted.

The foregoing résumé of research projects obviously includes many detailed lines of work of which further mention cannot be made here.

SUGGESTED RESEARCH

Food and feed utilization.

Numerous suggestions for further studies on problems relating to extended food utilization of potatoes have been made, some of which are now receiving a good deal of attention, particularly by State agencies. These suggested studies may be outlined as follows:

1. Agronomic-chemical investigations on the effect of different soils and varieties on the chemical composition, physical structure, and starch content of potatoes and studies on the chemical factors affecting the qualities of the potato.

2. Effect of environmental factors on seed value, yield, starch content, and disease resistance.

3. Control of insect pests, fungus growths, and virus diseases which interfere with the development of the potato-growing industry.

4. Enzymic changes in stored potatoes and investigation of the causes of blackening which occurs when late-stored potatoes are cooked.

5. Investigation of the effect of storage in the presence of inert gases at various temperatures on the chemical composition and vitamin content of potatoes.

6. Comparison of the vitamin C content of immature, mature, and stored tubers.

7. The use of potatoes as a succulent winter feed for livestock. Some feeding tests which have been conducted indicate that certain varieties of potatoes may find a definite place as a feed for livestock in sections of the country in which other succulent feeds are high in price.

Industrial utilization studies.

8. Research on the development of low-cost dehydration methods as well as on other means of lowering transportation and storage cost has been urged as essential in an industrial utilization program.

9. The drying of potatoes entirely by the use of heat is expensive, and in addition may cause undesirable changes in the starch. Recent studies have indicated the application of a preliminary chemical treatment in the solution of this problem. Such treatment greatly increases the permeability of the cell walls of the potato, making it possible to remove most of the water by mechanical means. There would be numerous advantages in the commercial use of dehydration methods of this sort, including the economical recovery of the expressed juices and the preparation of various products from the dried material. It has been strongly recommended that further extensive studies be made to develop new and improved drying methods.

10. Investigation of methods for the economical utilization of frozen potatoes.

11. Improved and economical methods for the production of alcohol from potatoes.

12. The production of plastic materials from starches.

13. Development of efficient potato starch and potato byproducts recovery plants adapted to conditions prevailing in the United States. To assist in the development of such factories the following investigations have been suggested:

(a) Determine chemically the starch-extracting efficiency of typical small plants, and ascertain the percentage of starch lost and the points in the process where losses occur; determine the causes for the present great variation in quality and develop improvements in equipment and operation which could be installed at moderate cost and which at the same time would greatly improve efficiency of operation of the small factories.

(b) Determination of the microbiological flora present in white-potato-starch factories and the establishment of better microbiological control to increase the efficiency of these plants.

14. The quality of domestic white-potato starch is quite variable. Studies looking to the establishment of grades coupled with substantial improvement in quality have been urged. When this is accomplished it will be possible to obtain the same price for domestic white-potato starch as for imported white-potato starch.

15. The residual pulp which remains after extraction of starch contains a certain proportion of starch which it is not profitable to recover by ordinary methods. In addition, it contains hemicelluloses and other constituents which could be recovered and utilized as by-products. It has been suggested that investigations be conducted looking to the development of economical methods for the recovery of such waste materials as well as methods for their profitable use.

16. The use of micro-organisms for the production of desirable transformations in potato starch. Further studies should lead to valuable commercial developments in this field.

17. Among the modified starches and starch derivatives are special modified and oxidized starches and dextrins. It has been urged that methods should be developed for producing these derivatives in a continuous process with starch production, and hence at lower cost.

18. Potato starch in the commercial purified form is a relatively low-priced pure carbohydrate raw material, from which a variety of chemical products can be made. It has been urged that investigations leading to the manufacture of these compounds be conducted with the object of making available new materials for the chemical industry.

19. Investigations leading to the determination of the structure of the potato-starch molecule have been strongly recommended. Studies of this type are described in detail under "Fundamental studies on cornstarch."

SWEETPOTATOES

Sweetpotatoes are the second largest vegetable crop in the United States and the largest in the South. During the 10-year period 1928-37 the average yearly commercial production was 70,723,000 bushels. In 1937 the total commercial crop was 75,393,000 bushels, with a farm value of about 65 million dollars. Approximately 60 million bushels were grown in the Atlantic and Gulf States from North Carolina southward.

An average of about 850,000 acres of sweetpotatoes has been grown in the last 10 years. About 450,000 acres were in the eight South Central States, about 275,000 in the four lower Atlantic States, about 66,000 in the four Central Atlantic States, and the remainder in the Central West and California.

The commercial crop of sweetpotatoes originates chiefly in four States. For many years Virginia was one of the leaders, shipping annually from 4,000 to 7,000 carloads. Louisiana has steadily increased its commercial output from about 1,000 carloads 10 years ago to more than 3,000 last year. Louisiana ships principally the Porto Rico variety of sweetpotato, which is steadily increasing in popularity. Tennessee, formerly one of the large shippers, has been gradually declining in relative importance. New Jersey is one of the largest shipping States, shipping the equivalent of 3,000 or 4,500 carloads a year by rail and truck.

The weighted average season price received by growers for sweetpotatoes over the last 10 years has ranged from \$1.18 a bushel in 1928 to \$0.54 a bushel in 1932. Since 1932, the average season price has been in the neighborhood of \$0.80 to \$0.90 a bushel. Last season (1937-38) the price averaged about \$0.87 a bushel.

The utilization of a typical sweetpotato crop may be indicated by the figures available for 1935. In that year a total crop of 83 million bushels was produced. Of this quantity, 3 million bushels were saved for seed, 46 million bushels were used at home for food, and an estimated 11 million bushels were fed to stock or wasted. From that year's crop some 23½ million bushels were actually sold at an average price of a little more than \$0.71 a bushel.

Much research has been directed toward improving the sweetpotato crop for food utilization. Many different varieties have been introduced to meet consumer demand in various sections of the country, and the effects of such factors as fertilizers, soil, and environment on

the yield and quality of the crop have been determined. Studies on methods of storing sweetpotatoes have resulted in the efficient curing and storage systems that now make it possible to have sweetpotatoes of good quality available in all food markets in the country in nearly every month of the year.

The food market for sweetpotatoes is somewhat inelastic, so that in years of high yields there are great surpluses of the marketable grade of this crop. Grading requirements for the food market are strict, and since the southern varieties tend to grow oversize there is annually a large quantity of culls consisting mainly of oversize sweetpotatoes. In the South these amount to about 20 percent of the crop. Some of the culls are fed to cattle, but for the most part they are wasted. These conditions have led to an insistent demand for some form of industrial utilization.

Many varieties of sweetpotatoes contain more than 20 percent of starch. Root starches are indispensable for certain purposes, and except for small quantities of white-potato starch and sweetpotato starch are not produced in the United States. Annual imports of starch, chiefly root starches, range from 300,000,000 to 450,000,000 pounds.

Experimental work was begun as early as 1895 with the object of establishing a sweetpotato-starch industry in the United States. Recently experimental work on this project has resulted in the establishment of a small commercial sweetpotato-starch plant operated by a local cooperative in the State of Mississippi. In 1938 approximately 165,000 bushels of sweetpotatoes were processed for the production of about 1,640,000 pounds of starch, which was used largely in the textile industry. The sweetpotato-starch industry, however, has hardly passed the experimental stage.

Up to the time of the establishment of this cooperative starch factory growers had been interested chiefly in obtaining as high a yield as possible of marketable sweetpotatoes, that is, potatoes of medium size and uniform shape. Since that time growers in the vicinity of the starch factory have been chiefly concerned with obtaining high yields of starch per acre. This has created a demand for research to find varieties of high starch content and has led to many other lines of research designed to develop high yields of starch per acre. Because of the need for further outlets for this crop, however, much of the present research is directed toward finding new food and industrial uses for it.

PRESENT RESEARCH

Present research projects are—

Biological investigations.

1. Agronomic studies: Extensive research is being conducted on spacing, time of planting, methods of propagation, and causes of marked differences in yield of adjacent or nearby hills.

2. Investigations on insect and disease control: Important research is in progress on the control of weevils and other insects that attack sweetpotatoes. Investigations are also being conducted on methods for the control and elimination of black rot and decay caused by fungus diseases.

Food utilization.

3. Storage studies: Studies are in progress to determine the effect of all conditions in storage houses, such as temperature and humidity, on the chemical composition and general suitability for food of all varieties of sweetpotatoes.

4. Dehydration studies: This research is intended to develop methods for dehydrating sweetpotatoes for food utilization. By regulating the temperature, humidity, and volume of air used in drying sliced sweetpotatoes, a product can be obtained which will keep for a long time and which when treated with water closely resembles the original sweetpotato. Sweetpotato flour has been produced by a process which involves cooking the potatoes, following by drying on heated drums or with spray-drying equipment.

5. Studies of the chemical composition and vitamin content: Studies are under way to determine the vitamin and carotene content of sweetpotatoes and the effect of various methods of storage and preservation on the vitamin content. Investigations are also in progress to determine the chemical composition of different varieties and the changes in composition that take place in storage.

6. Preparation of food products: Since all varieties of sweetpotatoes contain some sugar and the starch present can be readily hydrolyzed to maltose and glucose, many different types of sirups can be prepared from sweetpotatoes. Methods for removing colored compounds and products with an undesirable taste from sirups are being investigated. Sirups prepared from the purified starch are, of course, quite satisfactory in this respect. Research is also being conducted on the preparation of various types of breakfast foods and on such products as sweetpotato flour, sweetpotato chips, and vinegar, which have been prepared from sweetpotatoes on a laboratory scale.

Industrial utilization.

7. Improvement of sweetpotatoes for starch production: Studies are in progress on the effect of time of planting and digging; the type, quantity, and method of application of fertilizers; and the type of soil and variety of potatoes on the yield of starch, both in bushels per acre and in the average starch content of the potato. As a part of this work thousands of seedlings are being grown, and it is expected that strains of higher starch content and greater disease resistance than those now available will be developed. Investigations are also being conducted on the cause of "barren hills" in sweetpotato fields, which in some cases greatly lower the yield per acre.

8. Development of machinery for the production and harvesting of sweetpotatoes: It is expected that the industrial utilization of sweetpotatoes will result in large-scale operations and that mechanical means of planting, cultivating, and harvesting can be used to lower the cost of production of the crop. Experimental work is now under way on the development of improved machines for setting potato slips and vines and on harvesting equipment of the two following types: (1) Low-cost machines suitable for small-scale operations, which will deliver potatoes to the top of the ground, and (2) more expensive combination diggers and loaders, suitable for large-scale operations.

9. Dehydration studies of sweetpotatoes for storage: Sweetpotatoes are susceptible to the action of molds and other forms of rotting and do not keep well, particularly when they have been bruised by handling.

Moreover, considerable conversion of starch by amylases present in the sweetpotato occurs, with the result that storage procedures in use at present are not feasible for storing sweetpotatoes to be used commercially. Because of these conditions, investigations are being conducted to develop methods for breaking down the cell walls of ground or sliced potatoes by treatment with various chemicals so that a large proportion of the water can be pressed out by mechanical means, thereby greatly lowering the cost of dehydration and making the soluble substances in the potatoes available in a concentrated form. Laboratory work has also been done on the storage of sweetpotatoes under water in the presence of reagents capable of preventing decomposition of the starch. Such a storage process would eliminate dewatering costs and might possess advantages for use in some localities.

10. Development of commercial uses for sweetpotato starch: Studies on the chemical and physical properties of sweetpotato starch have been made, and its properties are also being determined by means of commercial tests in various industrial plants. The starch has been used in cotton mills for warp sizing, in laundries, in bakeries and confectionery manufactures, for test runs in beater sizing for paper, and for various types of adhesives. It has given excellent results.

11. Utilization of sweetpotato vines: The removal of sweetpotato vines from the fields would facilitate harvesting operations and make available from 0.5 to 2 tons of hay per acre. Dried vines compare favorably in feeding value with clover and soybean hay. Methods for removing vines from the fields and for drying or siloing them are being investigated.

12. Utilization of sweetpotato pulp from starch factory: Feeding tests with dairy and beef cattle are being conducted, and the results to date indicate that whereas crushed ear-corn and sugar-beet pulp have about equal value for milk and fat production, sweetpotato pulp has about 95 percent of the feed value of sugar-beet pulp.

SUGGESTED RESEARCH

The following is an outline of the recommendations made by various agencies for further research on sweetpotatoes:

Biological investigations.

1. Breeding studies: Present efforts to produce higher yielding, disease-resistant, better quality varieties that are better adapted to specific regions and purposes should be expanded.

2. Studies on plant variation: The causes of wide differences in yield of adjacent or nearby hills should be determined.

3. Control of sweetpotato diseases and insect pests: Research of this type is in progress and must necessarily be continued to insure the continual success of the crop.

4. Storage studies: Further improvement in the quality of stored potatoes is desirable. Expanded studies on the effect of all storage house variables, such as time, temperature, and humidity, on the suitability for food of all varieties of sweetpotatoes have been recommended.

5. Dehydration studies: Dehydrated sweetpotatoes and sweetpotato flour will keep for long periods of time. Further improvement in such methods of preserving sweetpotatoes for food utilization and

further research on equipment and on improvements in the quality of products obtained by dehydration are desirable.

6. Development of other food products from sweetpotatoes. Encouraging laboratory results have been obtained in preparing marketable food products, such as sweetpotato chips, sweetpotato flour, vinegar, and sweetpotato sirup. Further investigations on the preparation and manufacture of such products may be expected to lead to market outlets for sweetpotatoes and will assist in stabilizing their production.

Industrial utilization.

7. Agronomic-chemical investigations for the development of high starch content: A number of the present well-adapted varieties are relatively high in starch but are susceptible to serious diseases or have other undesirable features. The recently discovered methods of seed propagation, now available, will greatly facilitate the development of superior varieties.

8. Studies on planting and harvesting root crops: At present small-scale farming methods are used in planting and harvesting sweetpotatoes. For industrial utilization it is believed that this crop should be handled to a large extent by mechanical methods. Some preliminary investigations on planting and harvesting equipment have been encouraging, and it has been urged that these investigations be continued.

9. Storage for industrial utilization: It is urged that work be continued on low-cost dehydration methods and on other methods of storing sweetpotatoes for industrial use.

10. Preparation of sweetpotato flour for industrial use: The low-cost process of dehydration suggested in item 9 would make it possible to produce a cheap sweetpotato flour by simply grinding and screening the dehydrated potatoes. Further research on sweetpotato flour for the purpose of developing expanded market outlets has been recommended.

11. Development of low-cost root-starch manufacturing plants: Suggestions have been made that pilot-plant studies be conducted to develop suitable processes and to work out mechanical details of operation as well as to determine the most satisfactory types of mechanical equipment to be used for the processes developed.

12. Microbiological investigations: Microbiological control of the starch-manufacturing process is important, particularly in warm weather. Investigations having a twofold object have been suggested, i. e., (1) to study the microbiological flora present in sweetpotato-starch manufacturing plants and to establish the necessary microbiological control; and (2) to develop the use of microorganisms to produce desirable transformations in sweetpotato starch.

13. Marketing investigations: Investigations leading to the establishment of new markets for sweetpotato products offer a wide field for research.

14. Studies on the physical and chemical properties of sweetpotato starch: Research on the physical and chemical properties of sweetpotato starch, on the production of sweetpotato-starch derivatives, and on their physical and chemical characteristics is very important in developing a sweetpotato starch industry and in "stepping up" the value of products through production of derivatives suitable for a

greater variety of purposes than starch alone. It is suggested that this research be continued.

OTHER TUBER CROPS

There are a number of root crops now grown in the United States on a small scale from which certain carbohydrates, chiefly starch and inulin, can be produced. The survey revealed a rather widespread interest in expanded production of such crops. Chief interest in the root starches arises from the fact that they might provide raw materials now largely imported and that expanded production might serve to partially replace surplus agricultural crops. The development of such replacement crops to aid in the solution of the surplus problem was suggested by many agencies. A similar interest in expanded production of inulin-producing plants was noted. From these levulose, a conversion product of inulin, could be made available as an industrial chemical raw material.

MISCELLANEOUS STARCH-PRODUCING CROPS

About 300 to 400 million pounds of root starches, chiefly cassava, white potato, and arrowroot, are imported annually. Starches from different sources have different properties, and those that are entirely satisfactory for one industry may not meet all the requirements for other industries. Dasheen, canna, and arrowroot starches have widely varying properties. Therefore they may be used to supply all the domestic requirements for root starches for which white potato and sweetpotato starches may be unsuited. These crops can all be grown in various sections of the Atlantic and Gulf Coastal Plains from South Carolina to Texas.

Dasheen is best suited to comparatively low lands in the southern Coastal Plains. Yields of as much as 400 bushels per acre have been reported. The starch content of dasheen is exceptionally high, probably averaging about 25 percent. The granules are smaller than those of any other starch, the average diameter being about 3 to 4 microns. Such a starch would be expected to produce a paste of very high penetrating power and might have exceptional value for use in various industries, for example, in textile sizing, laundry work, and in the sizing of paper. Much of the area in the southern Coastal Plains section which would be suitable for this crop is cut-over timberland. The growing of a crop such as dasheen would be a step in the direction of greater diversification and would appear to be very promising in any plan of further agricultural development in the section, provided its culture can be adapted to American conditions.

The granules of canna starch are exceptionally large, the average diameter being about 40 to 60 microns. It has been reported to have exceptionally desirable qualities for the sizing of fine cotton textiles. These starches have been prepared on a laboratory scale, and some work has been done on the development of processes which could be used commercially for their extraction. Physicochemical investigations and some plant-scale tests of their properties have been made. The results obtained indicate that there will be an industrial demand for these starches when they can be produced in sufficient quantities to be placed on the market.

SUGGESTED RESEARCH

The following lines of research have been suggested to bring about expanded production and industrial utilization of miscellaneous starch-producing crops:

1. Agronomic-chemical investigations to determine the most suitable varieties of root starch-producing crops and the most satisfactory cultural and environmental conditions for their production.

2. Studies of the properties and uses of canna and arrowroot starches.

3. Investigation of methods for the extraction of starch from dasheen. A process practicable for commercial use will have to be devised. Because of the smallness of the granules and the presence of a substance or substances of mucilaginous consistency, the usual processes employed in the manufacture of root starches cannot be used.

4. Investigation of the composition and possibilities for the commercial utilization of byproducts available in connection with the production of starch from dasheen.

5. Study of the physical and chemical properties of dasheen starch to determine its value for industrial utilization.

6. A project to design, erect, and operate a pilot plant for semi-industrial development of the process devised for the manufacture of dasheen starch.

INULIN-PRODUCING CROPS

The tubers of Jerusalem artichokes, chicory, and dahlias contain a fairly high percentage of inulin, a substance composed of a group of carbohydrates somewhat similar to starch, which on hydrolysis yields levulose instead of dextrose. These crops, especially Jerusalem artichokes, have been investigated as a source of levulose. Problems involved in the purification of levulose sirups and crystallization of the sugar from these sirups have been solved, and pilot-plant methods for the production of the crystalline sugar have been developed. Further development of commercial methods for the production of crystalline levulose is needed, as well as methods for the direct production of levulose sirup. This sirup could be produced more cheaply than crystalline sugar and would supply equally well the commercial demand for levulose which results from its hygroscopic character and high solubility as compared with other sugars now on the market.

SUGGESTED RESEARCH

The following lines of research on inulin-producing crops have been suggested:

1. Investigation of the properties of inulin which may lead to its industrial utilization.

2. Investigation of methods of extraction and purification of inulin from Jerusalem artichokes and other inulin-producing crops.

3. The development of suitable methods for the direct production of levulose sirups for industrial utilization from artichokes and other inulin-producing crops.

4. Investigations on the production of power alcohol from inulin-producing crops. (See section on Motor Fuels under Corn, pt. II.)

5. Investigations on use of inulin as a raw material for the production of organic chemicals.

SUGAR CROPS

The most important domestic source of sugar in the United States is the sugar beet. In addition, large amounts of sugar and of sirup are produced from sugarcane and a considerable amount of sirup from sweet sorghum or sorgo cane. Other saccharine products are corn sugar and corn sirup, both of which are very important; honey, which is somewhat less so; and maple sugar and maple sirup, valued mainly on account of their flavor, the sugar produced being of only incidental value. The acreage devoted to sugar and sirup crops is shown on the accompanying map. The total of imports and domestic deliveries for consumption of raw beet and cane sugar in 1938 was 6,667,000 tons raw value. This total consumption was increased to over 7,500,000 tons by other sugars and by sirups. Of this amount, about 2,000,000 tons are accounted for by continental beet and cane sugar production. Cane and sorgo sirup production amount, in round numbers, to 200,000 tons. Estimates for other sugars (corn, with a very little, maple) are 200,000 tons, and for other sirups (corn, maple, honey), 600,000 tons.

About 73 percent of the sugar originating in continental United States is produced from the sugar beet. Annual production for the last 10 years has averaged well over a million tons. Table 12 shows the production, by States.

TABLE 12.—*Annual production of beet sugar, by States, average 1928-32, 1936, and 1937*

State	Average, 1928-32	1936	1937
	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>
California.....	139	310	289
Colorado.....	357	335	299
Idaho.....	70	91	106
Michigan.....	92	116	79
Montana.....	75	91	119
Nebraska.....	132	105	112
Ohio.....	28	28	13
Utah.....	90	70	85
Wyoming.....	78	84	92
Other States.....	98	74	92
Total.....	1, 160	1, 304	1, 286

In Florida and Louisiana, both sirup and sugar are produced from sugarcane, but in other cane-growing States only sirup is produced. Tables 13 and 14 show the distribution of production, by States and Territories.

TABLE 13.—*Annual production of cane sugar, sirup, and molasses, by States and Territories, average 1928-32, 1936, and 1937*

State or Territory	Equivalent in refined sugar ¹			Molasses		
	Average, 1928-32	1936	1937	Average, 1928-32	1936	1937
	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 tons</i>	<i>1,000 gallons</i>	<i>1,000 gallons</i>	<i>1,000 gallons</i>
Florida.....	19	48	62	1, 618	3, 673	4, 778
Louisiana.....	171	361	415	16, 226	32, 616	34, 447
Hawaii.....	935	974	883	-----	-----	-----
Philippine Islands.....	922	986	1, 044	-----	-----	-----
Puerto Rico.....	748	876	943	-----	-----	-----

¹ Sirup figures converted to, and included with, figures for sugar.

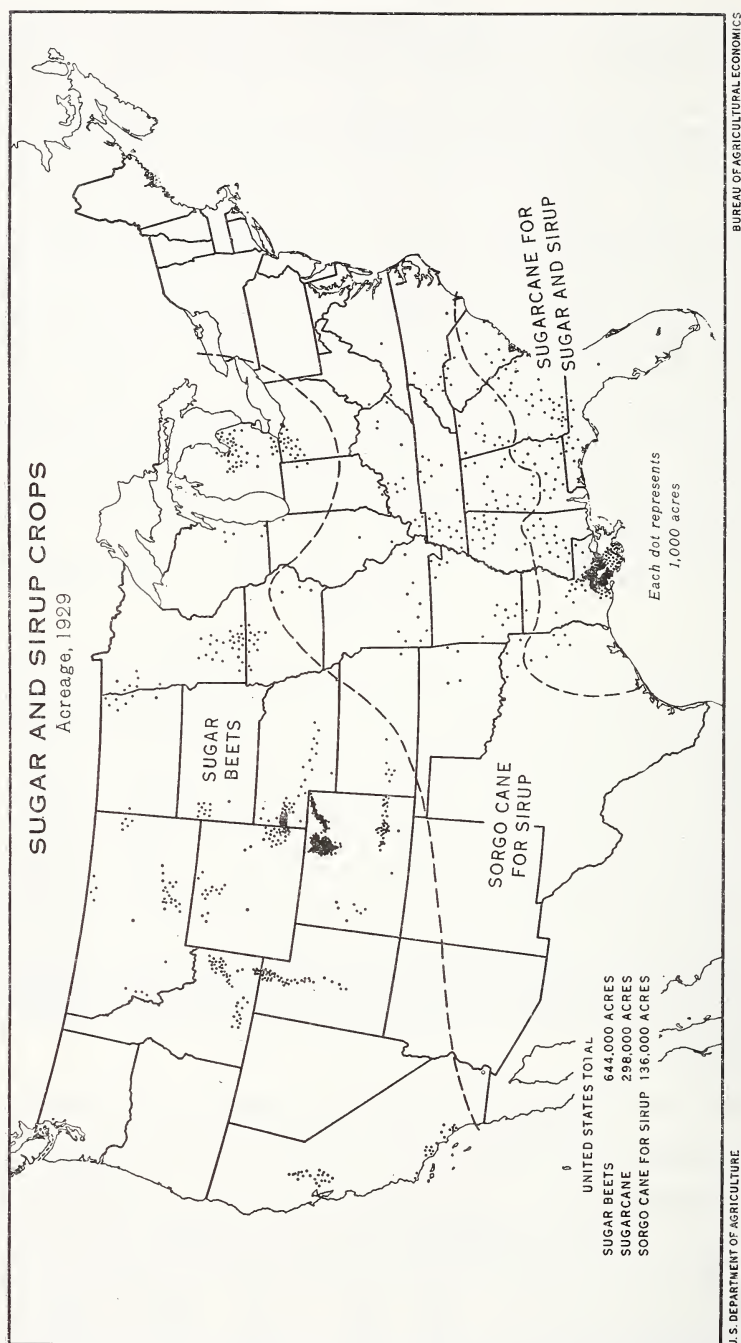


TABLE 14.—*Annual production and estimated value of cane sirup, by States, average 1928-32, 1936, and 1937*

State	Production			Estimated value	
	Average, 1928-32	1936	1937	1936	1937
	<i>1,000 gallons</i>	<i>1,000 gallons</i>	<i>1,000 gallons</i>	<i>1,000 dollars</i>	<i>1,000 dollars</i>
Alabama.....	2, 112	3, 321	3, 770	1, 495	1, 731
Arkansas.....	121	90	175	63	112
Florida.....	1, 657	2 145	1, 872	815	749
Georgia.....	4, 157	4, 830	5, 425	2, 125	2, 386
Louisiana.....	5, 371	7, 410	8, 410	2, 818	3, 118
Mississippi.....	2, 654	3, 640	4, 495	1, 748	2, 159
South Carolina.....	509	400	420	280	273
Texas.....	1, 189	840	768	504	461
Total.....	17, 800	22, 676	25, 335	9, 848	10, 980

The distribution of our sugar imports and exports is given in tables 15 and 16.

TABLE 15.—*Imports of raw cane sugar, average 1929-32, 1935-36, and 1936-37*

Source	Average, 1929-32	1935-36	1936-37
	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>
Cuba.....	2, 508, 189	2, 321, 649	1, 885, 093
Philippine Islands.....	847, 573	863, 623	949, 964
Other countries.....	41, 088	51, 898	128, 016
Total.....	3, 396, 850	3, 237, 170	2, 963, 073

TABLE 16.—*Exports of refined sugar, average 1929-32, 1935-36, and 1936-37*

Destination	Average, 1929-32	1935-36	1936-37
	<i>Tons</i>	<i>Tons</i>	<i>Tons</i>
United Kingdom.....	23, 983	28, 349	36, 555
Norway.....	3, 360	7, 270	870
France.....	1, 184	332	437
Netherlands.....	4, 822	4, 232	4, 012
Denmark.....	1, 275	492	556
Belgium.....	596	528	628
Italy.....	137	622	362
Irish Free State.....	45	6, 522	1, 420
Other European countries.....	346	29	2
Total exports to Europe.....	35, 748	48, 376	44, 842
Uruguay.....	5, 066	7, 955	0
West Indies and Bermuda.....	4, 646	2, 755	1, 788
British Africa.....	5, 459	287	254
Canada.....	2, 385	2, 175	2, 840
Mexico.....	1, 769	1, 211	104
Panama.....	4, 048	4, 102	4, 031
Newfoundland, Labrador.....	1, 378	6, 119	1, 278
Colombia.....	3, 713	8, 785	15, 622
New Zealand.....	911	392	0
Philippine Islands.....	714	124	190
Chile.....	333	266	21
China.....	58	208	105
Surinam.....	125	217	208
Venezuela.....	74	9	11
Other countries.....	1, 211	10, 956	4, 341
Total exports.....	67, 638	93, 937	75, 635

The distribution of sorgo-sirup production by States is shown in table 17.

TABLE 17.—*Production and estimated value of sorgo sirup, average 1928-32, 1936, and 1937*

State	Production			Estimated value	
	Average 1928-32	1936	1937	1936	1937
	1,000 gallons	1,000 gallons	1,000 gallons	1,000 dollars	1,000 dollars
Alabama.....	2, 516	2, 736	1, 960	1, 230	902
Arkansas.....	969	1, 160	1, 276	754	702
Georgia.....	898	975	924	488	508
Illinois.....	130	82	148	66	118
Indiana.....	143	135	195	108	156
Iowa.....	230	255	330	204	248
Kansas.....	134	60	100	48	75
Kentucky.....	725	585	780	410	507
Mississippi.....	1, 606	1, 520	1, 332	684	600
Missouri.....	646	341	552	290	414
North Carolina.....	1, 376	1, 260	1, 120	882	729
Oklahoma.....	208	50	84	33	50
South Carolina.....	404	336	276	185	152
Tennessee.....	1, 206	874	912	568	547
Texas.....	1, 115	1, 350	1, 716	675	858
Virginia.....	161	174	210	130	147
Total.....	12, 467	11, 893	11, 915	6, 755	6, 713

The data presented above show that only about one-third of domestic consumption requirements for sugar are met by the sugar crops of the continental United States. Existing sugar legislation divides, on the basis of fixed percentages, the United States sugar market among the various areas—continental, insular, and foreign—supplying this market. Any utilization of the sugar crops to replace surplus crops would require changes in the legislation.

The advantages of development through a research program of methods that will bring about greater and more efficient utilization of sugar products and byproducts, especially in the industrial field, is self-evident.

SUGAR BEETS

Sugar beets are grown exclusively for production of beet sugar. By the Sugar Act of 1937, approximately 23 percent of the national sugar requirement is to be supplied by beet sugar. The main beet-producing States, in order of importance, are Colorado, California, Nebraska, Michigan, Utah, Wyoming, Montana, Idaho, Washington, Oregon, Indiana, Illinois, Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, Kansas, and New Mexico. In 1938 a total of some 900,000 acres was planted, and, in addition, sugar-beet seed for use in planting a large part of the crop was grown on approximately 7,500 acres in Arizona, New Mexico, California, Utah, Nevada, Colorado, Texas, Washington, and Oregon. The crop of almost 11 million tons, estimated to produce about 1.5 million tons of sugar (approximately the quota limit), was processed in 88 factories.

Capital investment in farm lands, farm equipment, irrigation systems, factories, factory equipment, and transportation and power facilities directly concerned in sugar-beet production and beet-sugar manufacture may be placed conservatively at 350 million dollars. The capital investment in important subsidiary industries furnishing

supplies and services to the sugar-beet industry and in the livestock industry directly concerned in utilizing sugar-beet byproducts as feed would greatly increase this figure.

The factories engaged in processing sugar beets are near the farms on which the crop is grown. The States engaged in sugar-beet growing are, in general, removed from centers of population. Since the crop is marketed as sugar, transportation expense is minimized and western agricultural areas are enabled to enter relatively remote markets. In many of the intensive farming districts of Western States where crops are grown under irrigation, the beet crop is the cash crop around which the whole agricultural system centers.

For the 1938 crop, the fabricated products—beet pulp, molasses, and beet sugar—had a value of nearly 100 million dollars. The value to the farmers of the sugar beets they produced was approximately 63 million dollars. In addition, the farm value of the beet tops (used for feed) is estimated at 4 million dollars. The sugar-beet seed produced was worth, on the farm, approximately 1.2 million dollars.

Under the Sugar Act of 1937 the Secretary of Agriculture is directed to estimate the sugar-beet acreage on the basis of which payments are to be made to growers. For 1939 the estimate is for a total of 1,030,000 acres. Agricultural and chemical processes are closely allied in the sugar-beet industry. For the problems of this crop, study of new methods of utilizing the crop and its byproducts appears to offer tangible opportunities.

Beet pulp obtained as a byproduct from beet-sugar factories offers an excellent opportunity for investigation with the objective of more profitable utilization. This material at present is used extensively as a feedstuff. Wet pulp at the sugar plant is valued at only \$1 per ton, so that it serves as a very cheap source of raw material.

As a byproduct of the manufacturing process, waste lime accumulates around the factory, finding only occasional use as a soil amendment. The disposal of pulp water, Steffen's waste water, and lime sludge is annually presenting a more acute problem as stream-pollution laws become more rigid. Obviously, the elimination of these wastes through utilization is most desirable. The sugar beet and such allied strains as could readily be developed by plant breeding offer economical carbohydrate sources for use in fermentation industries.

PRESENT RESEARCH

Present research dealing with sugar beets and byproducts from the beet-sugar industry includes:

Agricultural research.

1. Varietal improvement in sugar beets, including studies on sucrose content and purity as affected by cultural practices and available varieties, and development of improved varieties for higher sugar content and disease resistance.

2. Development of strains of sugar beets more suitable for culture under varying climatic and soil conditions existing in different areas, including studies on the relation to growth of tillage practices, types of fertilizer used, and methods of fertilizer application.

3. Studies on the conditions and treatment of soils that affect the stand, growth, yield, and quality of sugar beets.

4. Improvement in production of sugar-beet seed, and determination of the relative value and productivity of sugar-beet seed produced annually instead of biennially.

Fundamental research.

5. Plant physiological studies of sugar synthesis in the sugar beet and the effect of storage.

Processing.

6. Sugar-beet machinery investigations, including the design and testing of machinery for use in cultivation and harvesting of beets.

7. Improvements in sugar-factory operation.

8. Investigation of substances other than sucrose in the sugar beet and beet wastes as to nature, removal, influence on sugar quality, and possible utilization.

9. Investigation of the production of various grades of beet sugar by means of improved manufacturing processes.

SUGGESTED RESEARCH

It is recognized that work on many of the items listed below is already under way. They are repeated merely for the sake of emphasis and to indicate the widespread interest in research of this character.

1. Investigations to broaden the scope of sugar-beet production in the United States by further agronomic researches and by development of new and important uses of the sugar beet, such as direct use for alcohol production and dehydration for use as cattle feed.

2. Investigations to utilize more efficiently farm byproducts and crop wastes, for example, production of staple feeds for livestock and poultry from beet tops and crowns and utilization of wastes, such as screenings and seed stalks, in the sugar-beet seed enterprise.

3. Extension of studies on beet molasses as a source of organic compounds, and fermentation studies on lactic acid production from beet and cane molasses.

4. Further investigations of beet-pulp utilization as a base substance in fermentation industries, as a source of pectin and derived substances such as mucic acid, and as a source of hemicellulose and tartaric acid.

5. Further studies on organic and inorganic substances recoverable from Steffen's wastes as well as from lime wastes.

6. Correlated studies with the objective of preventing stream pollution.

7. Raffinose utilization.

8. Further studies on chemical methods for evaluating the quality of sugar beets.

SUGARCANE

Because the sugar situation has, from time to time, put producers in the United States in a difficult position, attempts have been made to allocate to each producing area a portion of the market, restricting the amount of sugar entering the market from each area.

The revival of the Louisiana sugar industry is a classical example of the possibilities of a coordinated research program. Louisiana is the main source of cane sugar in the continental United States. The crop is grown on the alluvial soils of the Mississippi Delta, where a large population is wholly dependent upon sugarcane for a livelihood.

No other cash crop for which an outlet is in sight is so well adapted to the region. In 1926, production of sugar in Louisiana had dropped from a maximum of 400,000 tons to 47,000 tons; the farmers dependent upon cane faced a desperate situation, and in groping for a remedy planted cane lands with other crops, principally cotton, rice, and potatoes. Since 1926, disease-resistant varieties released for commercial culture by the Government have brought about acre-yields of sugar which now reach or exceed former high levels, and the curve of production during the 12 years up to 1938 points sharply upward. The trend in yields is the outcome of a comprehensive program of sugarcane breeding initiated in the United States in 1920, comparable to the earlier, persistent efforts for cane varietal improvement in the tropical and temperate zone sugar-producing areas of Java and India, respectively. The 1938 crop is estimated at 514,000 tons of sugar. Prices are low, however, and more profitable utilization of byproducts and surpluses is indicated as one means of compensating for prevailing low prices in this highly competitive industry.

Some of the peat soils of southern Florida have been used very successfully for sugarcane production on a limited scale. Up to the present, only the more highly mineralized peats in areas where cold damage is minimized have given promise of permanency. Performance of the crop in other nearby peat areas is erratic and the period of tests too short to permit evaluation, but, as in Louisiana, attention to varieties adapted to the region may result in greater crop stability.

Sugarcane is grown for sirup production in Mississippi, Alabama, Georgia, South Carolina, and Texas, as well as in Louisiana and Florida, and it is important as a cash and subsistence crop on between 200,000 and 300,000 farms. In 1934 about 25.6 million gallons of sugarcane sirup with a farm value of approximately 11.6 million dollars was produced. In these areas land occupied in the growing of cane is largely suitable for producing other crops of which surpluses now exist. In years following poor sirup markets there is a noticeable drift to these other crops. Standardization of the sirup, orderly marketing, and new uses for waste and byproducts are problems that need attention.

In addition to sucrose, there are byproducts from the cane-sugar industry, principally molasses, filterpress cake, and bagasse. The profitable disposal of these byproducts is of considerable importance to the sugar industry, and while efforts have been directed toward this end, there is a great deal more that can be done. One of the byproducts, molasses, constitutes an important raw material that is used extensively in animal feeds and in the fermentation industries. Bagasse is discussed in the section of Agricultural Wastes (p. 110).

PRESENT RESEARCH

Present research dealing with sugar (sucrose) manufacture and the manufacture of farm sirups is devoted largely to chemical and technological problems involved in the manufacturing processes. Investigational work dealing with utilization of byproducts from the sugar industry has been carried out to only a limited extent by the sugar manufacturers themselves. In general, they prefer to dispose of these byproducts at the best prices obtainable without establishing any extended program of research aimed at more profit-

able utilization. Manufacturing industries using these products, particularly fermentation industries that use molasses, have carried out research on the problems involved in utilization of the products for their particular industry.

Present investigations pertaining to sugarcane and its products and byproducts include:

Agricultural research.

1. Sugarcane breeding to develop new varieties improved as to disease resistance and in other respects, and tests for field and mill yield of new and improved sugarcane varieties.

2. Agronomic studies on varieties of sugarcane for sugar and sirup production and for forage; on drainage of cane land; and on increasing yields per acre.

3. Composition factors affecting the value of sugarcane for forage and other purposes.

4. Investigation of deterioration of sugarcane at harvesting time.

Processing for cane sugar and cane sirup.

5. Improvements in quality and uniformity of cane sirup and sugar.

6. Improvements in refining processes and equipment for the purposes of simplification, economy, and increased yields.

7. Investigation of the properties of, and the efficiency and economy of using, commercial activated carbons, including carbons produced from factory wastes, in refining cane sugar at the factory; and production of improved decolorizing agents.

8. Investigation of substances in sugarcane juice that interfere with clarification.

Analysis and testing.

9. Improvement of methods and apparatus for the examination and analysis of sugarcane products, including development of new testing methods and instruments for the measurement of color, viscosity, etc.

New uses for cane.

10. Investigation on the composition of juice from different portions of sugarcane stalks with reference to utility for different purposes.

11. Improved methods of utilizing cane juices by diversification of products and the production of sugars of more uniform quality.

Utilization of sucrose.

12. Study of invertase and acid inversion products of sucrose and their utility.

13. Isolation of crystalline levulose from invert sugar.

14. Use of sugar in the preparation of nutrient media for bacteriological work.

15. Use of sucrose as a diluent for dyes.

16. Preparation of sugar-phenol resins and their use in protective coatings.

Utilization of molasses.

17. More complete exhaustion of molasses for additional recovery of sugar.

18. A rational and improved procedure of rum manufacture from molasses.

19. Value of cane molasses in rations of farm animals.

20. Effect of molasses in conjunction with various proportions of corn and soybean oil upon the quality of beef.

21. Production of organic solvents from molasses by fermentation processes.

22. Improvement in bacterial processes for obtaining organic solvents from blackstrap molasses.

23. New and extended uses for blackstrap and other low-grade molasses.

24. Improvement of molasses for baking and other industrial uses.

25. Composition of molasses and methods of analysis.

26. Dehydration of molasses to powdered form.

Utilization of wastes:

27. Disposal of spent bone black.

28. The industrial utilization of sugar-factory filter-press cake, such as for fertilizers and fuel.

29. Investigations on recovery of sugarcane wax.

30. Recovery of gums and other byproducts.

SUGGESTED RESEARCH

A number of important phases of research dealing with the industrial utilization of sugar and sugar products apparently can be developed on a rather extensive scale. The quantities of sugar and molasses and other saccharine products produced is so great that many individuals associated with this industry are of the opinion that there is primary need of investigating the larger potential outlets for sugar and sugar products, such as the use of sugar in concrete and mortars, as a preservative for wood, and as a cheap raw material for the manufacture of organic chemicals of all kinds. Since sugar byproducts, such as molasses, are usually cheaper sources of sugar than the refined sugar itself, these materials are usually considered first in a utilization program of this kind. While it is true that a certain amount of investigational work along these lines is being conducted, particularly with respect to utilization of molasses for the production of alcohol and other solvents by fermentation processes, the field is so large that it offers great possibilities for development research. Continuation and expansion of much of the present work was frequently suggested as desirable.

Suggestions on research to develop new outlets for sugar and sugar byproducts, as submitted by research institutions and by the industry itself, are given below. Many of these suggestions are applicable to beet sugar and molasses as well as to cane. Research is already being conducted on some of the suggested types of work listed below, and such items are included merely for the purpose of emphasizing the need for their continuation and expansion.

Utilization of sugar.

1. A comprehensive study of the possibilities of using sugar as a raw material in processes such as fermentation, chemical degradation, and pyrolysis to produce new chemical substances that might serve as important outlets for surplus sucrose.

2. Further investigation on the recovery of sucrose by means of alcohol.

3. More study on the effect of sugar on mortar and concrete.
4. Development of an anhydrous sugar product suitable for use as a filler for paints and varnishes.

Utilization of molasses.

5. Study on the utilization of molasses in ensilage and other feeds.
6. Further study on the use of molasses as a nutrient for yeast.
7. Further study on the production of power alcohol from sugar products, since this offers a possible outlet for very large amounts of such products.
8. Continued investigation of other possible new outlets for large quantities of sucrose and sucrose byproducts such as in preservation of wood (crosssties).
9. Study on the utilization of molasses in conjunction with other materials in road building.

Utilization of wastes.

10. Study on the production of cane-juice beverages.
 11. Study on the utilization of cane tops.
 12. Production of plastics from cane byproducts.
- For a discussion of sugarcane bagasse, see the section on Agricultural Wastes, p. 110.

SORGO

Sorgo in its numerous varietal forms is adapted to a wide range of conditions in the United States, from the Gulf States to Minnesota and from coast to coast, but the center of potential production is a wedge-shaped area with its base extending from eastern Colorado to southern Texas and its apex resting in western Virginia. Nearly 300,000 acres are devoted to sorgo for sirup production, and about 10 times that amount to sorgo for forage. On many thousands of small farms sorgo is considered a valuable subsistence and small cash crop. Since 1929 the farm value of sorgo sirup has been between 6 and 8 million dollars a year.

Sorgo, like the other sugar crops, cane and beet, is not native to the New World, and during the scant 80 years since it was introduced the plant has proved a good subject for improvement by breeding. With numerous, divergent characteristics, readily separated and recombined in breeding, it is likely that sorgo will become more important in the course of time as varieties better adapted to local conditions in different parts of the country are developed.

PRESENT RESEARCH

Present investigations pertaining to sorgo sirup include:

1. Development of new varieties.
2. The production of sugarcane-sorgo hybrids.
3. Studies of varieties for sirup manufacture.
4. Method of making sorgo sirup and factors affecting quality.
5. Production of sorgo sirups of improved quality and greater uniformity.
6. Marketing investigations on sorgo sirup.
7. Investigation of sorgo as a source of sucrose and dextrose.

MAPLE PRODUCTS

Maple sugar is produced on many farms in the Northeastern States, notably Vermont, New York, and northeastern Ohio. Table 18 shows the production by States. It is a side-line product on nearly all farms and a welcome source of additional income. As the sugar season comes in early spring, thousands of farmers are able to tap their maple trees and boil down the sap with little extra labor and no interference with other farm work.

The farm price per pound of maple sugar ranges roughly from 25 to 30 cents. Maple sirup brings the farmer from \$1.50 to \$2 per gallon.

TABLE 18.—*Production of maple sugar and sirup by States, average 1928-32, 1936, and 1937*

State	Sugar made			Sirup made		
	Average 1928-32	1936	1937	Average 1928-32	1936	1937
	1,000 pounds	1,000 pounds	1,000 pounds	1,000 gallons	1,000 gallons	1,000 gallons
Maine.....	17	1,343	1,520	34	27	36
Maryland.....	25	17	12	24	19	36
Massachusetts.....	77	25	89	60	33	61
Michigan.....	48	21	16	118	96	99
New Hampshire.....	117	45	64	78	45	67
New York.....	425	232	291	745	740	643
Ohio.....	48	15	12	329	340	401
Pennsylvania.....	126	52	62	217	104	155
Vermont.....	945	556	417	1,011	930	991
Wisconsin.....	9	4	7	66	69	73
United States.....	1,838	1,310	1,490	2,682	2,403	2,562

¹ Includes 325,000 pounds not produced on farms.

² Includes 500,000 pounds not produced on farms.

Although these locally important side-line crops in restricted areas in the northeastern section of the United States have a very definite value as producers of cash income, maple products are luxury items in the average market. The price fluctuates somewhat from season to season, but there is no question of surplus. Some research has been devoted to the improvement of products, standards for grading, and the utilization of sirup and sugar for food specialties. No suggestions for further research on maple products were received.

HONEY

Honey production in the United States is very widespread, about 175,000,000 pounds being produced yearly in the 48 States. Besides being a cash crop that brings some income to over half a million beekeepers, the economic importance of beekeeping for cross-pollination of certain crops, particularly fruit crops, is very great. It is estimated that the value of beekeeping for cross-pollination is several times as great as the total value of the honey produced. However, since the honey is the main source of cash income derived from beekeeping, its profitable disposal will always be an important consideration.

Beeswax is an important byproduct in the preparation of strained honey, and a source of additional cash income to apiaries equipped for processing.

Although there are an increasing number of commercial apiaries, beekeeping is usually incidental to other crop interests. The honey crop varies from year to year with the weather conditions which affect the blossoms on which the bees depend. Most honey, both in the comb and strained, is sold for direct consumption, but considerable amounts of strained honey, especially the dark-colored, strong-flavored grades, go to the bakery and confectionery trades.

There is some research in progress on the utilization of beeswax and honey for industrial purposes, and the suggestions received were for further research along this line.

OTHER SUGARS

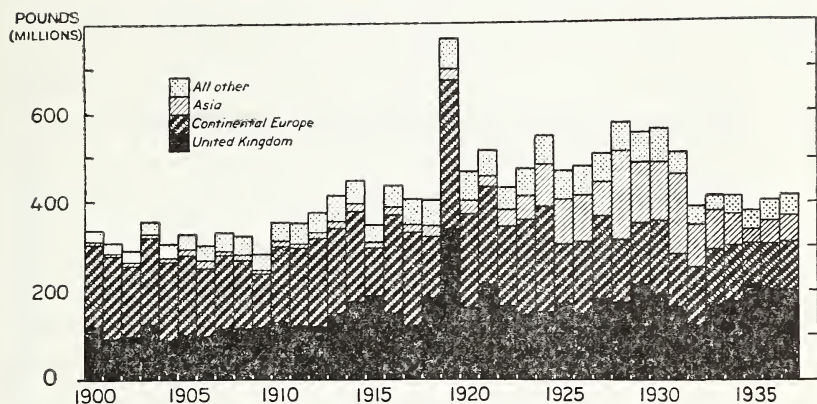
Some work has been done in State and Federal laboratories on the production of levulose from Jerusalem artichokes. Since artichokes offer a promising substitute crop on acreage removed from production of other crops on account of surplus, there is a demand for further research on artichoke production and processing. (See section on Other Tuber Crops, p. 449.)

Among the suggestions offered for the development of new products from various fruits, vegetables, and other crops and crop byproducts, some were concerned with a search for rare sugars as well as other organic compounds. It is expected that this will be a part of the fundamental research program of the laboratories, and it is hoped that from such work some extremely valuable results may be obtained.

TOBACCO

Tobacco is grown commercially in significant quantities in 20 States, and about 6 other States produce small quantities on a commercial basis. The principal producing areas are shown in the accompanying map. In the 3-year period 1935-37 the crop averaged 1,335,296,000 pounds and was produced on 1,535,600 acres; the estimated farm value averaged nearly 277 million dollars. The United States crop in 1937 represented approximately 23 percent of the world production of tobaccos, whereas in 1920 the United States production represented about 27 percent of the world production. There is a steadily increasing production of certain types of tobacco throughout the world, especially the flue-cured type for cigarettes. Foreign production, aided by tariff and other means, is now competing in foreign markets with the American product. It is resulting in a reduction in the net potential exports of all the American types, especially in net exports of the fire-cured and dark air-cured types. These are heavy-bodied strong tobaccos. The graphs and accompanying tables show exports of United States tobacco. The first of these shows the exports of all types combined and the principal countries of destination. The second shows the exports of the several types since 1923. Attention is called especially to the exports of fire-cured and dark air-cured types. The accompanying chart graphically portrays the steady decline in the exports of these tobaccos in recent years.

Tobacco: Exports from the United States, 1900 to Date



U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

Exports of tobacco to Asia and Continental Europe show important decreases in recent years, whereas exports to the United Kingdom remain at a relatively high level. Total exports, although still higher than in the years previous to the World War, are on a lower level than during the years 1919 to 1931, inclusive.

Tobacco: Exports¹ from the United States by countries, 1900 to 1937

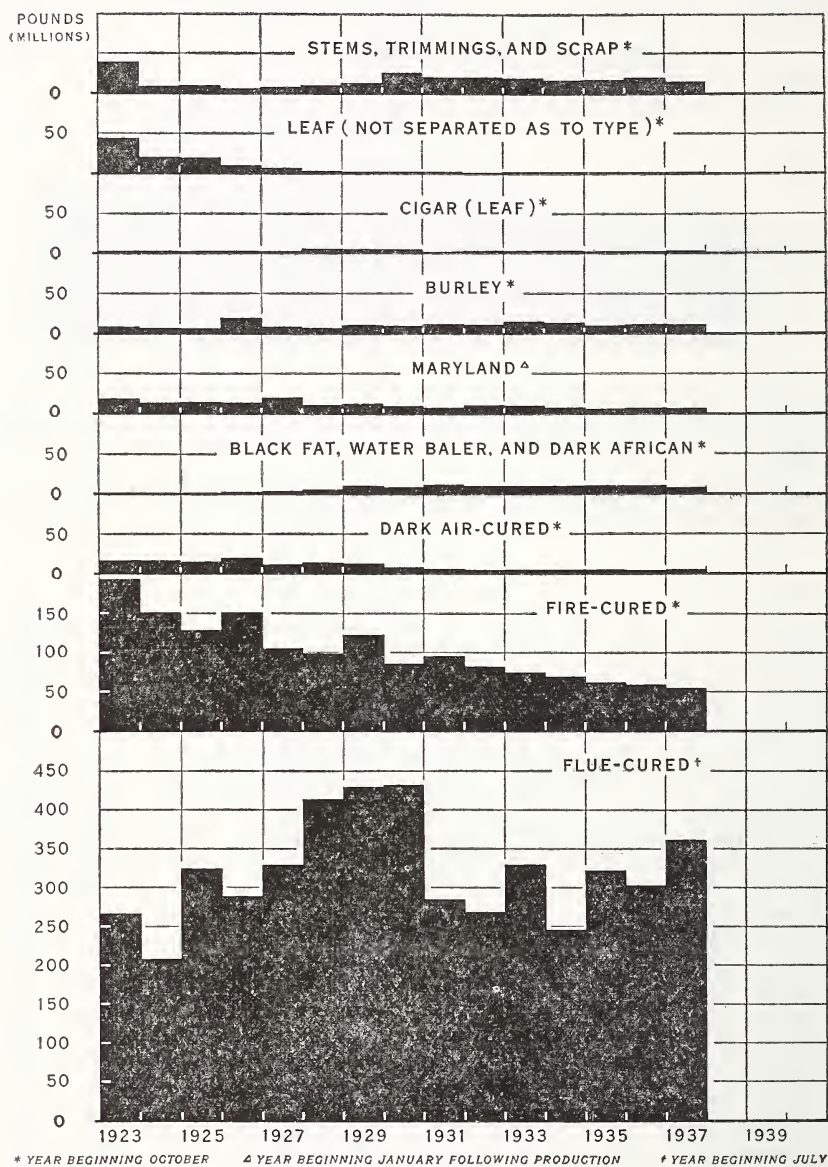
Year ²	United Kingdom	Continental Europe	Asia	Other countries	Total
	Million pounds	Million pounds	Million pounds	Million pounds	Million pounds
1900.....	121.8	184.0	3.6	25.2	334.6
1901.....	93.0	185.7	2.5	25.7	306.9
1902.....	98.7	158.5	5.1	29.1	291.4
1903.....	125.1	197.0	4.5	30.9	457.5
1904.....	89.4	176.2	5.4	34.4	305.4
1905.....	101.8	179.5	9.8	37.1	328.2
1906.....	98.0	153.0	14.4	36.9	302.3
1907.....	116.4	165.2	5.6	44.3	331.5
1908.....	116.1	153.9	8.5	44.5	323.0
1909.....	118.6	121.6	5.0	37.5	282.7
1910.....	131.0	170.0	8.6	43.8	353.4
1911.....	122.5	174.6	6.5	48.0	351.6
1912.....	120.8	198.0	10.2	46.4	375.4
1913.....	150.1	191.2	12.8	60.1	414.2
1914.....	174.8	262.9	17.1	52.1	446.9
1915.....	189.3	107.3	9.4	42.0	348.0
1916.....	150.6	219.4	16.6	49.9	436.5
1917.....	122.6	268.8	16.8	58.2	406.4
1918.....	183.5	136.8	24.0	59.6	403.9
1919.....	338.8	333.8	24.0	69.3	765.9
1920.....	162.7	209.1	29.4	66.5	467.7
1921.....	214.9	218.6	22.8	59.1	515.4
1922.....	165.2	175.2	36.6	50.9	430.9
1923.....	146.4	213.0	51.8	63.3	474.5
1924.....	151.0	237.2	92.7	65.7	546.6
1925.....	171.1	132.9	101.1	63.4	468.5
1926.....	149.7	160.1	104.2	64.8	478.8
1927.....	182.6	183.7	76.0	64.0	506.3
1928.....	173.7	140.3	196.8	64.6	575.4
1929.....	214.6	136.9	138.6	65.2	555.3
1930.....	193.8	162.4	132.5	72.3	561.0
1931.....	162.9	116.3	175.4	48.9	503.5
1932.....	121.6	130.9	91.6	43.7	387.8
1933.....	172.9	124.2	89.0	34.3	420.4
1934.....	180.0	123.1	74.2	41.7	419.0
1935.....	216.2	91.5	31.1	42.4	381.2
1936.....	206.5	100.2	52.4	47.7	406.8
1937.....	203.3	107.6	60.4	46.5	417.8

¹ Stems, trimmings, and scrap not included. Export weight.

² Data 1900-1917, fiscal year; 1918 to 1937, calendar year.

Compiled from Foreign Commerce and Navigation of the United States and official records of the Bureau of Foreign and Domestic Commerce.

TOBACCO: EXPORTS FROM THE UNITED STATES BY TYPES, 1923-37



Tobacco: Exports from the United States by types, 1923 to 1937¹

Year	Flue-cured	Fire-cured	Dark air-cured	Black Fat, Water Baler, and Dark African	Maryland	Burley	Cigar leaf	Other leaf ²	Stems, trimmings, and scrap
	Million pounds	Million pounds	Million pounds	Million pounds	Million pounds	Million pounds	Million pounds	Million pounds	Million pounds
1923.....	266.0	194.5	16.2	(³)	18.1	7.7	1.5	44.9	39.2
1924.....	207.5	151.0	16.8	(³)	12.8	6.0	.7	20.8	8.6
1925.....	324.4	129.3	14.4	(³)	13.9	5.8	.7	19.4	9.4
1926.....	288.7	150.4	19.8	0.4	13.6	18.1	.6	9.7	5.9
1927.....	328.9	105.9	11.5	1.2	20.0	7.1	.6	5.9	7.4
1928.....	413.9	98.5	12.9	4.5	10.9	6.2	4.4	1.7	9.3
1929.....	429.9	122.6	12.1	8.2	11.6	9.7	4.3	.2	12.4
1930.....	432.7	85.9	7.2	7.6	9.7	8.7	3.7	.1	26.1
1931.....	285.5	95.8	5.3	10.4	7.5	11.0	.8	.1	20.9
1932.....	269.7	82.2	3.4	8.4	10.2	10.4	1.3	(⁴)	20.9
1933.....	330.3	75.0	3.4	8.3	9.2	13.9	1.5	.1	18.6
1934.....	244.5	70.6	4.5	9.7	7.1	12.0	1.2	.1	16.2
1935.....	322.8	62.8	4.5	10.1	4.7	8.9	.7	.1	17.5
1936.....	302.6	59.9	2.7	9.5	6.1	11.2	.7	.1	20.5
1937.....	361.9				5.3				

¹ Crop years: Flue-cured, year beginning July; Maryland, year beginning January following production (i. e., 1923 data are exports of 1922 crop); all other, year beginning October.

² Prior to Jan. 1, 1929, includes a part of exports of other types not reported separately, beginning Jan. 1, 1929, Perique only.

³ Prior to Jan. 1, 1927, included with other leaf.

⁴ Less than 50,000 pounds.

As indicated in the chart, the important United States export tobaccos are flue-cured and fire-cured. Exports of fire-cured and dark air-cured tobaccos have been curtailed by decreased total consumption of these kinds in foreign countries, by increased foreign production, and by the operation of trade barriers. While increased production and unsettled world conditions have affected foreign markets for United States flue-cured leaf, the increasing total foreign consumption of this kind of tobacco in the form of cigarettes, particularly in the United Kingdom, has maintained flue-cured exports at a relatively high level.

Such reduction in exports of fire-cured and dark air-cured tobaccos has developed unsalable surpluses of these tobaccos, which have been relieved by the diversion of 45 million pounds to byproduct uses under the operation of the Agricultural Adjustment Administration, by production control under Agricultural Adjustment Administration farm programs during 1934 and 1935, and by agricultural conservation programs of 1936, 1937, and 1938. The situation is further complicated by the world trend toward lighter, milder tobaccos.

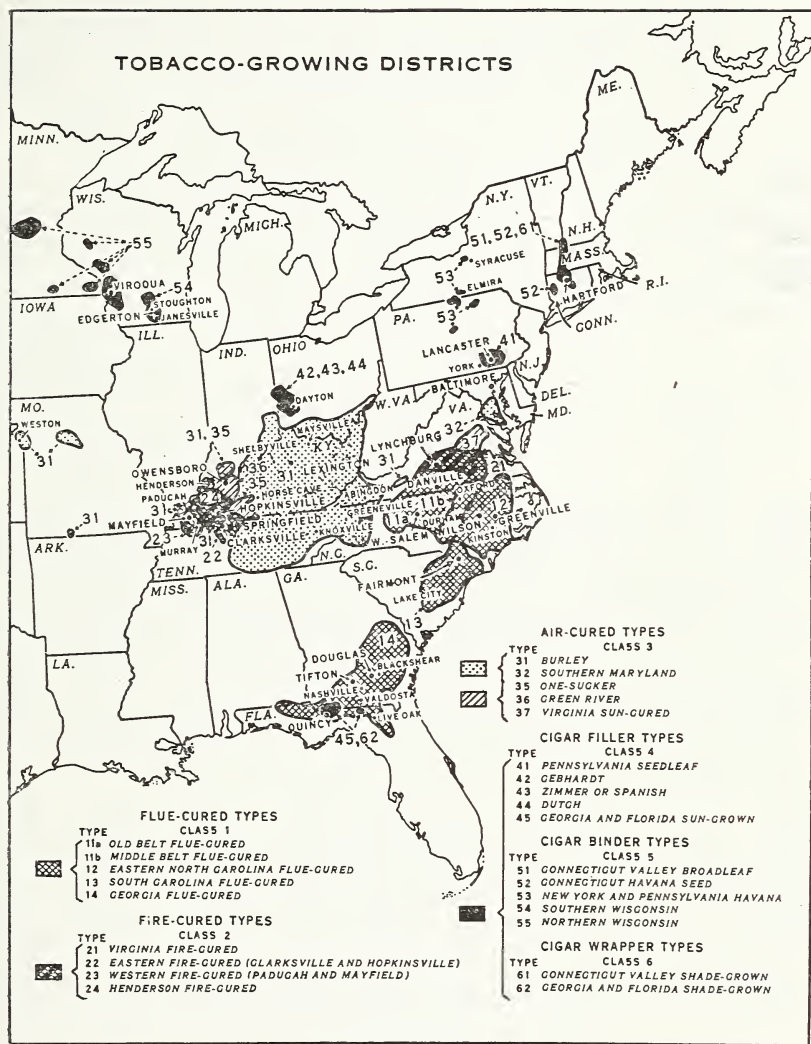
Tobacco is peculiar among agricultural crops in that varietal characteristics as well as the methods employed in drying or curing the freshly harvested crop determine its "type" or adaptability for specific uses. To a less extent types and qualities are determined by the character of soil upon which the tobacco is grown and by other environmental factors.

The method of curing is the major factor for classification; viz, flue-curing (high heat, 190° F.), fire-curing (medium heat, 100° F.), and air-curing (no artificial heat). Varietal, environmental, and soil differences further determine the classification. For example, the air-cured group is thereby further classified as burley, Maryland, cigar tobaccos, sun-cured, and dark air-cured tobaccos. Each of these types possesses physical and chemical properties that are characteristic and that determine its economic uses. The acreage, yield, production, and farm value of the six principal groups of United States tobaccos for the periods 1919-21 and 1935-37 are shown in table 19.

TABLE 19.—*Acreage, yield, production, and value of tobacco, by types*

Type	Average annual—							
	Acreage		Yield per acre		Production		Farm value	
	1919-21	1935-37	1919-21	1935-37	1919-21	1935-37	1919-21	1935-37
	<i>Acres</i>	<i>Acres</i>	<i>Pounds</i>	<i>Pounds</i>	<i>1,000 pounds</i>	<i>1,000 pounds</i>	<i>\$1,000</i>	<i>\$1,000</i>
Flue-cured.....	777,300	904,000	623	866	483.882	782.975	140.973	170.169
Fire-cured.....	309,100	136,900	753	814	232.800	111.482	35.218	11.860
Burley.....	319,600	340,900	797	825	254.580	281.095	58.828	67.202
Maryland.....	28,700	36,800	758	767	21.763	28.208	4.347	6.363
Dark air-cured.....	130,200	41,200	799	833	103.972	31.332	13.126	3.368
Cigar.....	175,600	75,800	1,245	1,282	218.688	97.204	49.262	17.728
Miscellaneous.....	3,800	-----	991	-----	3,764	-----	752	-----
Total.....	1,744,300	1,535,600	-----	-----	1,319,449	1,335,206	302.506	276,690

A map showing the areas of commercial production in the United States follows:



The estimated 1938 production as reported by the Crop Reporting Board for November 1, 1938, is shown in table 20. The report of the same board, showing production of all types by States, is shown in table 21.

TABLE 20.—*Tobacco by class and type, 1937 and 1938*

Class and type	Type No.	Yield per acre (pounds)			Production (thousand pounds)		
		Average, 1927-36	1937	Preliminary, 1938	Average, 1927-36	1937	Preliminary, 1938
FLUE-CURED							
Virginia.....	11	657	720	760	67,145	72,000	71,440
North Carolina.....	11	712	800	800	176,147	209,600	199,200
Total old belt.....	11	695	778	789	243,292	281,600	270,640
Eastern North Carolina belt.....	12	771	925	850	257,562	305,250	263,500
North Carolina.....	13	827	985	975	43,678	71,905	64,350
South Carolina.....	13	761	965	910	76,724	108,080	91,910
Total South Carolina belt.....	13	782	973	936	120,403	179,985	156,260
Georgia.....	14	796	930	925	64,270	73,935	90,650
Florida.....	14	747	840	950	4,525	14,112	15,200
Total Georgia and Florida belt.....	14	793	914	929	68,795	88,047	105,850
Total flue-cured.....	11-14	748	878	853	690,051	854,882	796,250
FIRE-CURED							
Virginia.....	21	750	790	790	21,820	19,355	17,064
Kentucky.....	22	772	840	725	31,104	25,200	19,575
Tennessee.....	22	823	850	820	50,184	42,500	36,900
Total Clarksville and Hopkinsville.....	22	803	846	784	81,288	67,700	56,475
Kentucky.....	23	759	810	790	25,212	21,060	18,486
Tennessee.....	23	801	840	850	5,933	7,140	6,375
Total Paducah.....	23	768	817	805	31,145	28,200	24,861
Henderson Stemmiag (Kentucky).....	24	775	850	890	5,220	2,125	2,225
Total fire-cured.....	21-24	787	830	792	139,473	117,380	100,625
AIR-CURED (LIGHT)							
Ohio.....	31	817	875	850	11,986	13,475	12,410
Indiana.....	31	780	860	875	8,288	11,180	10,238
Missouri.....	31	913	900	1,000	5,003	5,850	8,000
Kansas.....	31	805	850	1,050	1,258	425	735
Virginia.....	31	1,024	1,125	1,050	7,617	12,938	12,705
West Virginia.....	31	683	725	725	3,304	3,408	3,552
North Carolina.....	31	778	975	975	4,552	8,775	8,775
Kentucky.....	31	756	905	875	207,626	276,930	270,375
Tennessee.....	31	838	930	900	44,566	69,750	65,700
Total Burley.....	31	778	912	886	293,070	402,731	392,490
Southern Maryland.....	32	721	700	780	25,500	25,200	30,030
Total air-cured (light).....	31-32	774	896	878	318,630	427,931	422,520
AIR-CURED (DARK)							
Indiana.....	35	825	850	925	1,621	510	462
Kentucky.....	35	793	915	790	14,916	21,045	16,353
Tennessee.....	35	784	875	820	2,532	3,062	2,460
Total One-Sucker.....	35	795	908	796	19,068	24,617	19,275
Green River (Kentucky).....	36	785	900	865	21,098	19,800	15,224
Virginia sun-cured.....	37	730	785	800	3,256	2,983	2,240
Total air-cured (dark).....	35-37	788	896	824	43,422	47,400	36,739

¹ Short-time average.

TABLE 20.—*Tobacco by class and type, 1937 and 1938—Continued*

Class and type	Type No.	Yield per acre (pounds)			Production (thousand pounds)		
		Average, 1927-36	1937	Preliminary, 1938	Average, 1927-36	1937	Preliminary, 1938
CIGAR FILLER							
Pennsylvania seedleaf.....	41	1, 241	1, 220	1, 350	39, 326	28, 678	32, 400
Miami Valley (Ohio).....	42-44	914	975	900	19, 851	15, 698	14, 490
Georgia.....	45	1, 010	1, 120	1, 150	487	448	460
Florida.....	45	1, 010	1, 120	1, 180	623	784	944
Total Georgia and Florida sun-grown.....	45	1, 005	1, 120	1, 170	1, 062	1, 232	1, 404
Total cigar filler.....	41-45	1, 112	1, 120	1, 169	60, 346	45, 600	48, 294
CIGAR BINDER							
Massachusetts.....	51	1, 549	1, 560	1, 200	408	156	120
Connecticut.....	51	1, 530	1, 540	1, 200	13, 925	13, 860	10, 440
Total Connecticut Valley broadleaf.....	51	1, 531	1, 540	1, 200	14, 332	14, 016	10, 560
Massachusetts.....	52	1, 511	1, 530	1, 260	7, 425	7, 038	5, 670
Connecticut.....	52	1, 511	1, 570	1, 200	5, 922	3, 140	2, 400
Total Connecticut Valley Havana seed.....	52	1, 511	1, 542	1, 242	13, 346	10, 178	8, 070
New York.....	53	1, 207	1, 275	1, 350	1, 054	1, 148	1, 620
Pennsylvania.....	53	1, 287	1, 600	1, 450	424	320	290
Total New York and Pennsylvania Havana seed.....	53	1, 233	1, 335	1, 364	1, 477	1, 468	1, 910
Southern Wisconsin.....	54	1, 310	1, 320	1, 480	20, 428	14, 520	22, 348
Wisconsin.....	55	1, 255	1, 430	1, 430	12, 477	10, 582	13, 013
Minnesota.....	55	1, 125	1, 150	1, 150	1, 107	460	805
Total Northern Wisconsin.....	55	1, 248	1, 416	1, 410	13, 584	11, 042	13, 818
Total cigar binder.....	51-55	1, 383	1, 439	1, 363	63, 168	51, 224	56, 706
CIGAR WRAPPER							
Massachusetts.....	61	1, 013	940	850	1, 163	1, 128	1, 020
Connecticut.....	61	1, 003	890	820	5, 203	5, 340	5, 248
Total Connecticut Valley shade-grown.....	61	1, 004	898	825	6, 366	6, 468	6, 268
Georgia.....	62	1, 081	900	1, 100	483	630	880
Florida.....	62	1, 038	900	1, 100	2, 386	1, 890	2, 640
Total Georgia and Florida shade-grown.....	62	1, 044	900	1, 100	2, 870	2, 520	3, 520
Total cigar wrapper.....	61-62	1, 023	899	906	9, 411	8, 988	9, 788
Total cigar types.....	41-62	1, 209	1, 226	1, 225	132, 925	105, 812	114, 788
United States.....	All	791. 8	897. 1	875. 1	1, 325, 243	1, 553, 405	1, 470, 922

² Including loss after harvest as a result of hurricane and flood tentatively estimated as follows: Broadleaf (type 61), 3,140,000 pounds; Havana seed (type 52), 1,650,000 pounds; and Shade (type 61), 900,000 pounds.

TABLE 21.—*Tobacco—yield per acre and production, 1927-38*

State	Yield per acre (pounds)			Production (thousand pounds)		
	Average, 1927-36	1937	Prelim- inary, 1938	Average, 1927-36	1937	Prelim- inary, 1938
Massachusetts.....	1,415	1,411	1,174	9,024	8,322	16,810
Connecticut.....	1,373	1,314	1,058	25,196	22,340	18,088
New York.....	1,207	1,275	1,350	1,054	1,148	1,620
Pennsylvania.....	1,241	1,223	1,351	39,749	28,990	32,690
Ohio.....	877	926	876	32,502	29,173	26,900
Indiana.....	788	860	877	10,017	11,690	10,700
Wisconsin.....	1,287	1,364	1,461	32,905	25,102	35,361
Minnesota.....	1,125	1,150	1,150	1,107	460	805
Missouri.....	913	900	1,000	5,003	5,850	8,000
Kansas.....	805	850	1,050	258	425	735
Maryland.....	721	700	780	25,560	25,200	30,030
Virginia.....	698	767	793	99,838	107,276	103,449
West Virginia.....	683	725	725	3,304	3,408	3,552
North Carolina.....	753	884	845	481,939	595,530	535,825
South Carolina.....	761	965	910	76,724	108,080	91,910
Georgia.....	800	931	927	65,192	75,013	91,990
Florida.....	850	856	978	7,534	16,786	18,784
Kentucky.....	761	894	855	305,175	363,160	342,238
Tennessee.....	827	894	867	103,214	122,452	111,435
United States.....	791.8	897.1	875.1	1,325,243	1,553,405	1,470,922

¹ Including loss after harvest as a result of hurricane and flood, tentatively estimated as follows: Massachusetts, 1,575,000 pounds; and Connecticut, 4,125,000 pounds.

² Short-time average.

In the United States flue-cured, burley, and Maryland tobaccos are consumed principally in cigarettes. A large portion of burley tobacco, the dark air-cured types, and certain grades of flue-cured tobacco are processed for smoking and chewing tobaccos. The fire-cured tobaccos are used in the manufacture of snuff and cigars of the Italian type, and to a lesser extent for twist chewing and pipe smoking. Cigar tobaccos are used, as their name implies, for the manufacture of cigars and for scrap chewing tobacco. The adaptations of the various types and subtypes in the tobacco industry are complicated and need not be considered further here. Brands of tobacco products have been developed upon the particular qualities of these various types, either alone or in blends of two or more, and interchangeability of one type for another is usually impractical. It is of interest to note the trend in the United States during recent years in the consumption of the several types of tobacco products and the increasing per capita consumption as shown on the accompanying chart.

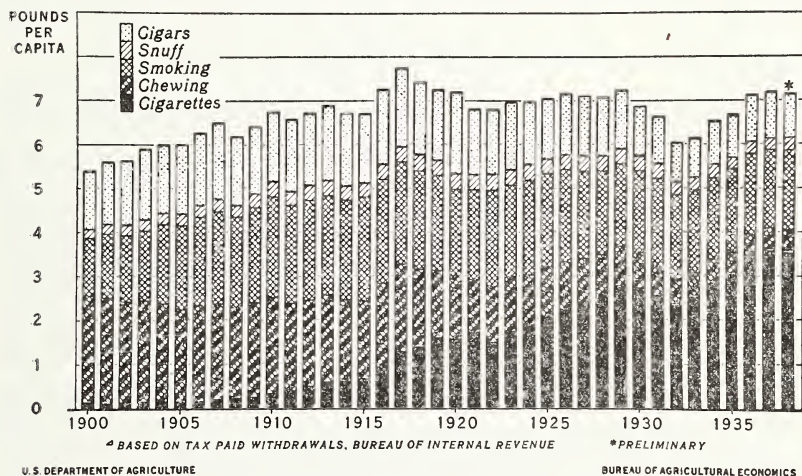
This shift in consumption is reflected by the shift in production of the several tobacco types during the past 18 years, wherein the light air-cured and flue-cured types have increased in production and all other types have decreased. The demand in the United States for cigarettes made from blends of flue-cured, burley, Maryland, and varying amounts of Turkish tobaccos has been rapidly increasing, whereas the consumption of snuff, chewing tobacco, pipe tobaccos, and cigars has been stationary or has declined during the same period. The same trend to the milder cigarette in preference to the use of heavier tobaccos in other forms is noted generally throughout the world.

Such decline in foreign and domestic demands for the heavy tobaccos, of course, has forced the producers to make adjustments. Large-scale adjustments of this kind, however, are difficult to make quickly. The growers of Virginia, Tennessee, Kentucky, and Indiana, who produce the fire-cured and dark air-cured tobaccos, have only recently realized

the full significance of the situation abroad. They had enjoyed, for nearly 150 years, a very substantial market in many foreign countries. It has been difficult for these producers to reduce their production rapidly enough to keep it in line with the decreasing demands and to prevent the accumulation of apparently unsalable stocks that are now classified as surplus.

Furthermore, the trade practices and customer preferences over many years have established a certain accepted classification of grades. These grades have ranged from a relatively medium-bodied, light-colored grade of smoking leaf, preferred by Holland, to the heavy dark leaf, preferred by the domestic snuff manufacturer. Roughly, there have been six main groups or grades for export and one really important group demanded by the domestic manufacturers. If exports of these tobaccos continue to decline at the rapid rate of the past few years, it is conceivable that it will not be long before the producers of fire-cured tobaccos will have left but two important outlets; namely, domestic snuff and nicotine extraction.

TOBACCO PRODUCTS: CONSUMPTION PER CAPITA
IN THE UNITED STATES, 1900 TO 1938 Δ



The total per capita consumption of tobacco products was on an upward trend until 1917. The chart shows the striking changes which have taken place in the relative importance of different products, and the effect of changing economic conditions on consumption. During the depressions following 1920 and 1929 consumption of tobacco products declined.

The domestic snuff manufacturers at the present time use from 25 to 30 percent of the whole crop of fire-cured tobaccos. The rest of the crop is divided among the various foreign markets; a small domestic cigar, chewing, and smoking market; and the extraction business. Experience shows that probably from 30 to 40 percent of every crop will be unsuitable for snuff manufacture. With a continuing decline in foreign demand, an increasing surplus will be available.

During the past 4 years the average farm prices for the four fire-cured types has ranged from 6.4 cents to 13.4 cents per pound. It is estimated that 93 percent of these crops was sold for leaf purposes for export, snuff, cigars, and chewing and smoking tobaccos and the remainder was sold for byproduct uses.

Changing world conditions, heretofore mentioned, are tending to limit the outlets for these tobaccos to snuff and byproduct uses. In view of this fact, the grower's income from these types of tobacco will decrease unless the price of snuff leaf can be increased or unless the byproducts value of the tobacco remaining after snuff requirements are met can be raised. It is believed that chemical and other research may develop commercially useful products that will add an appreciable value over and above what the byproducts industries can now afford to pay.

PRESENT RESEARCH

Present research in the United States on tobaccos falls broadly into four classes. The first group of studies is concerned with leaf tobacco for smoking or other human consumption; the second with other uses to which tobacco may be put, which may be described as byproduct uses; the third with the production of tobacco especially for nicotine; and the fourth with economic studies. In the outline of present research which follows, the investigations considered here are classified under the first three groups, briefly described as research on leaf tobacco, research on byproduct uses, and the production of tobacco for nicotine.

LEAF TOBACCO

Breeding.

Plant-breeding studies are being widely conducted with the following objectives:

1. Improving growth characteristics, quality, and yield in standard and hybrid strains of all types.
2. Development of strains that are resistant to the following diseases: Mosaic; black root rot; brown root rot; black shank; Granville wilt; fusarium wilt; downy mildew; wildfire; and angular leaf spot.
3. Development of strains of the *tabacum* species that possess a low nicotine content.
4. Development of strains and hybrids of the *rustica* species that possess a high nicotine content.
5. Development of strains of the Turkish types of tobacco adapted to American conditions.
6. The above work is being supplemented by broad studies of the genetics, taxonomy, and cytology of the genus *Nicotiana*.

Agronomic research.

7. Biochemical studies of several important tobacco types in several of the tobacco-producing areas. These bear upon the nutritional and environmental factors in relation to the plant responses, including the effects upon combustibility, aroma, nicotine content, and other elements of quality.
8. Studies of the effects of cropping and soil management practices, including the effects of rotation, cover crops, and natural vegetation upon the yield and quality of tobacco.
9. Studies of the effects of rainfall and of irrigation methods upon the yield and quality of tobacco.
10. Experiments upon the structural responses induced by varying the distance of planting, height of topping, and extent of suckering as they affect quality and yield.

11. Fertilizer studies to determine nutritional requirements with reference to quality, yield, and resistance to disease for all tobacco types.

12. Studies on the adaptability of various soil types to the production of flue-cured tobacco.

Pathological investigations.

13. A study of the mosaic disease of tobacco as regards its effect upon yield and quality and methods for its control.

14. Fundamental researches on tobacco mosaic as a basis of approach to the broader general subject of filterable viruses and their function in plant and animal physiology.

15. Researches on nematodes and methods for their control by chemical and agronomic means.

16. Studies of the taxonomy, distribution, and control of the organisms causing tobacco diseases, including black root rot, brown root rot, black shank, Granville wilt, fusarium wilt, wildfire, angular leaf spot, frog eye, downy mildew, etc. The methods of control include sanitation, rotation practices, chemical methods, etc.

17. Methods for control of downy mildew in the seed bed by fumigation with benzol, paradichlorobenzene, and other hydrocarbons, and also by means of chemical sprays.

18. Studies of the transmission of tobacco diseases through manufactured tobaccos.

19. Studies of organisms which cause deterioration of tobacco in the curing barn, and of methods for their control.

Entomological research.

20. Studies of insects attacking the growing tobacco plant, and development of means for their control.

21. Studies to develop measures for eliminating, or reducing to a minimum, insects which attack tobacco in storage and in the growers' packhouses.

Chemical research.

22. Determination of the physical characteristics, chemical composition, and smoking qualities of the several types of flue-cured tobaccos, as influenced by soil, weather factors, and liming.

23. Studies of the role of nitrogen, potash, phosphorus, sulphur, chlorine, magnesium, and the trace elements, including manganese, boron, iron, and copper, in the nutrition of the tobacco plant.

24. Studies of the chemical changes occurring during the growth, curing, and storage of tobaccos.

25. Chemical studies of tobacco smoke and the use of smoke data in devising methods for the treatment and proper blending of leaf tobacco.

26. Studies of factors influencing the burning quality of tobacco.

27. Effect of degree of maturity of tobacco at harvest on its chemical composition and smoking qualities.

28. Investigation of flavors in tobacco.

29. Correlation of stalk positions of the leaf and smoking quality of tobacco.

30. Effect of various processing operations on the chemical composition of leaf tobacco. This includes the correlation of chemical composition and physical characteristics with tobacco quality in the endeavor to improve manufactured products.

31. Fermentation studies on cigar tobacco.

Curing.

32. Biochemical investigations of the curing processes of flue-cured, burley, fire-cured, cigar, and Maryland tobaccos.

33. Investigations concerning the relative practicability of coal, fuel oil, and electricity as a source of heat in flue-curing.

34. Supplemental application of atomized water in the curing process for fired tobaccos.

35. Application of artificial heat in the curing of air-cured types.

Grading.

36. Studies of the factors that determine quality and grade of tobacco.

37. Establishment of standards for tobacco grades.

BYPRODUCT USES

Nicotine.

38. Development of new applications of nicotine in insect control.

39. Investigation of fixed nicotine compounds as stomach poisons for codling-moth larvae (apple worms). These compounds include nicotine-bentonite, nicotine-peat, etc.

40. Use of nicotine tannate for the control of the corn earworm.

41. Control of the adult codling moth and other orchard and field pests by methods based upon the vaporization of liquid nicotine. This includes chemical and engineering studies of methods for vaporizing and applying nicotine as a fumigant.

42. The use of nicotine compounds for the control of external and internal parasites of poultry and other livestock.

43. Development of activators for nicotine to permit the use of lower concentrations, and thus lower the cost of application when used as a contact insecticide.

44. Studies on the use of new carriers and diluents for nicotine; for example, the use of finely ground tobacco fortified with commercial nicotine extract and carrying larvicidal oils.

45. Development of chemical methods for determining the small amounts of nicotine in spray deposits.

Byproducts other than nicotine.

46. Use of denicotinized tobacco extract as an emulsifying agent for insecticides and in industrial products.

47. Use of ground tobacco as a conditioner in phosphate fertilizer to prevent caking.

48. Research on methods of recovering organic acids and potash from tobacco stems.

49. Use of low-grade tobacco as a source of organic material and fertilizer elements in certain soil-management practices.

50. Studies of the occurrence of alkaloids other than nicotine in various species of *Nicotiana*.

51. Studies on denicotinized tobacco extract. This material has been found to be a very efficient blood coagulant and shows promise in the field of medicine.

52. Studies on nicotinic acid. This acid can be made from nicotine and apparently has specific therapeutic properties in the curing of pellagra in man and black tongue in dog.

PRODUCTION OF TOBACCO FOR NICOTINE

53. In addition to the utilization of surplus and off-grade tobaccos, and tobacco wastes as outlined above, breeding experiments, coupled with soil, environmental, and cultural studies for the production of high-nicotine tobaccos with high yields per acre, are under way. This work is being done with various species in pure lines and species crosses, and is being carried on in regions outside of established tobacco-growing areas, including California and Oregon. The aim is to produce new nonsmoking tobaccos, specifically for industrial uses.

SUGGESTED RESEARCH

An enumeration of the various research subjects submitted as suggestions to survey workers for investigation by means of laboratory studies and field work follows. Some of these subjects are already receiving attention from numerous investigators, as is indicated in the section on present research.

LEAF TOBACCO

Breeding.

1. Development of useful varieties of tobacco resistant to the various tobacco diseases.
2. Development of low-nicotine strains of tobacco for cigar, cigarette, and pipe-smoking uses.
3. Development of domestic "Turkish" types to be substituted for the imported Turkish types.

Agronomic research.

4. Studies of fertilizers for tobacco and their effects upon growth, quality, and resistance to diseases.
5. Studies of the effects of trace elements upon the growth and quality of tobacco.
6. Studies of the effects of soil types and other environmental factors upon the nicotine content of tobacco.
7. Studies of the effects of distance of planting, height of topping, and extent of suckering upon the structural responses of tobacco plants, and of these factors, as well as degree of maturity, upon the smoking and other qualities of tobacco.
8. Studies of the effects of fertilization and storage on the flavor, burning, and other qualities of tobacco.

Pathological investigations.

9. Studies of the effects of various diseases, such as mosaic, upon the quality of tobacco for manufacturing purposes.
10. Development of efficient and economical methods for the control of the blue-mold disease.
11. Studies of the pathogeny of the organisms causing the various tobacco diseases.
12. Study of the tobacco mosaic disease to obtain fundamental knowledge concerning filterable viruses.

Entomological research.

13. Studies of the biology and control of insects which attack the growing plant, including the leaf, stem, root, and root stalk.

14. Studies of the biology and control of the insects attacking tobacco in the curing barn and storage places.

15. Control of the cigarette beetle and tobacco moth in open storage warehouses.

Chemical research.

16. Chemical analyses, and measurements of the physical characteristics, of burley and the several types of cigar tobaccos, similar to the work already done on flue-cured tobaccos.

17. Determination of the influence of soil, cropping practices, and weather factors on the chemical composition and smoking and other qualities of burley and cigar tobaccos, including the influence of soil micro-organisms.

18. Studies concerning the smoking qualities of cigar tobaccos, including the factors which determine smoking quality, the effect of varying the method of preparing the filler, and means for eliminating throat irritants.

19. Studies concerning the smoking qualities of cigarettes larger than the present 3-pounds-per-thousand cigarettes, with the view of encouraging larger consumption of leaf tobacco.

20. Study of the aroma-producing compounds in tobacco.

21. Vacuum fumigation of hogshhead tobacco prior to export.

Curing.

22. Fundamental studies of the processes used in the curing of tobacco, including determination of the effects of temperature, humidity, and time.

23. Application of high-frequency electrical fields or ultra-violet radiation to accelerate the aging of tobacco.

24. Fermentation studies on cigar tobaccos.

25. Studies on the improvement of curing methods, such as the adaptation of coal and oil burners and electrical heaters in preparing flue- and air-cured tobaccos, and the use of moist air in preparing fire-cured tobaccos.

26. Studies on the effects of oxidizing and reducing gases on the curing and aging of tobacco.

27. Studies on the development of bleaching methods for dark-colored tobaccos to make them adaptable for cigarette purposes.

28. Studies of the aging process in storage of tobacco with a view to shortening the storage period.

29. Development of community curing centers.

30. Standardization of curing methods.

31. Development of farm storage houses best suited for storing tobacco which is to be held for better marketing conditions.

BYPRODUCT USES

Nicotine.

32. Studies on the more extended use of nicotine and various nicotine compounds in insecticides and veterinary remedies.

33. Improvement in the efficiency of nicotine and its compounds as insecticides by means of carriers and activators, and the use of im-

proved engineering methods designed to lower cost of application, particularly of vaporized nicotine for field, tree, and greenhouse crops.

34. Use of tobacco powder as a carrier for other insecticides.

35. Development of fungicides compatible with the fixed nicotine compounds.

36. Studies to determine the fate of the fixed nicotine compounds, especially nicotine-peat and nicotine-bentonite, in the soil.

37. Recovery of nicotine from tobacco factory drying machines.

38. Preparation of nicotine sulphite and nicotine hydrochloride for commercial uses similar to those of nicotine sulphate.

39. Farm extraction of nicotine for local farm use.

40. Development of methods for removing nicotine-bentonite and other fixed nicotine compounds from sprayed fruits.

41. Study of the practicability of increasing nicotine recovery from tobacco by means of oxidants.

42. Development of factory methods for extracting nicotine and other constituents from green, uncured tobacco.

43. Experiments on the use of hydrocarbon oils and carbohydrates as carriers for nicotine.

44. Investigation of nicotine in combination with polybasic organic acids, such as phthalic acid, with the aim of producing water-insoluble compounds or oil-soluble compounds.

45. Investigation of the nicotine-combining power of the silicate and aluminosilicate minerals like bentonite.

46. Investigation on the addition of various organic bases to nicotine-bentonite with the aim of promoting retention of the nicotine compound on foliage or fruit during rains.

Byproducts other than nicotine.

47. Studies on the suitability of nicotine-free tobacco extracts, containing gummy and resinous substances, for use as insecticide spreaders.

48. Studies on the fertilizer value of farm scrap tobacco and means for sterilizing tobacco waste to be used as fertilizer.

49. Fundamental chemical investigations on the components of various tobaccos, and application of results in the industrial utilization of tobacco.

50. Studies on the recovery of organic acids (citric and malic), essential oils, pigments, pectin, and other constituents from green tobacco, and on the extraction of such of these products as occur in the cured leaf.

51. Study of the occurrence and isolation of alkaloids other than nicotine in the various species of *Nicotiana* and their hybrids.

52. Study of the feasibility of recovering potash from tobacco waste for emergency demands.

53. Manufacture of fiberboard from tobacco waste, including low-grade leaf and stems, with or without other raw materials.

54. Utilization of storm-damaged tobacco.

55. Studies on the value of tobacco leaf, stems, or midribs and stalks as sources of cellulose for the manufacture of cigarette and other papers and synthetic fibers.

56. Studies on the fats, oils, alkaloids, and other substances contained in tobacco seed.

57. Preparation of nicotine derivatives and stimulation of the study of such compounds, for example, nicotinic acid, for medicinal uses.

58. Study of means for preparing from tobacco extract, in purified form, a valuable blood-coagulating principle which it has been found to contain.

PRODUCTION OF TOBACCO FOR NICOTINE

59. Development of tobacco varieties within the several species of *Nicotiana* which produce high acre yields and are high in nicotine and other commercially valuable substances.

60. Development of a variety of tobacco producing a high acre yield of nicotine which is especially adapted to California and other areas that are capable of producing tobacco yields higher than those secured in established tobacco areas.

FORAGE CROPS

Forage crops include grasses, legumes, and other plants for hay, silage, and grazing. While these crops are utilized directly in industries to only a slight extent and there seems to be little prospect for expansion of such utilization, they are extremely important in the animal industries, such as dairying, beef-cattle raising, and wool growing, and are closely related to the yield and quality of industrial products obtained from the animals produced on farms and ranches. They are important also as soil-improvement crops, thereby indirectly affecting the yield and quality of succeeding crops when used in a scheme of crop rotation. For these reasons they have received attention in the Survey.

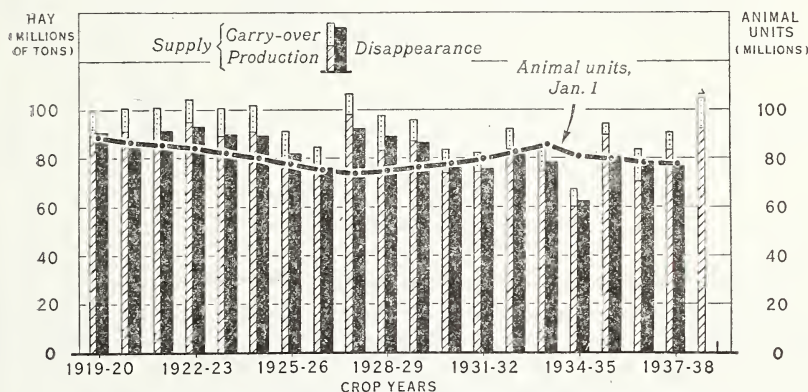
Since vegetative feedstuffs are practically indispensable in raising all classes of farm animals, hay has always been one of the most important crops in the United States. Hay production and consumption in relation to livestock since 1919 is shown graphically in the accompanying chart. Various grasses (timothy, bluegrass, Sudan grass, millet, etc.), legumes (alfalfa, clovers, cowpeas, soybeans, etc.), and cereal plants (rye, oats, barley, etc.) cut before maturity constitute the hay crops. Some of these are also used for grazing and as silage. To a large extent the various hays are interchangeable. In addition to the hay and forage crops grown on tilled land, wild hay, pasture grasses, range grasses, and other plants are highly important in animal husbandry. However, since most of the present and suggested investigations on vegetative feedstuffs relate to crop plants, attention will be chiefly confined to them.

The process of haymaking varies with the particular crop and climatic conditions. Moisture conditions, duration and intensity of sunlight, and type of plant are factors to be considered in the curing of hay for satisfactory storage. As much as 25 to 50 percent, and possibly in extreme cases even more, of the nutritive value of alfalfa hay may be lost through improper curing. Hay is generally baled when not used locally. In this form it may be conveniently handled, stored, and shipped.

The preservation of forage as silage rather than as hay possesses many advantages, especially in dairying, and this method of preservation may be used for almost any feed plant, although corn and sorghum are perhaps the most important. Silage is made by the natural fermentation of the green fodder.

The relative importance of the various forage crops is indicated in table 22, which shows acreage, production, and farm value for the year 1937. The figures for farm value do not take account of the pasturage and soil-improvement values of forage crops, for which no data are available.

HAY PRODUCTION AND CONSUMPTION IN RELATION TO LIVESTOCK*



* BASED ON PRODUCTION OF TAME AND WILD HAY, HAY REMAINING ON FARMS MAY 1, AND JANUARY 1 INVENTORIES OF HAY-CONSUMING ANIMALS ON FARMS IN THE UNITED STATES

▲ PRELIMINARY

U. S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

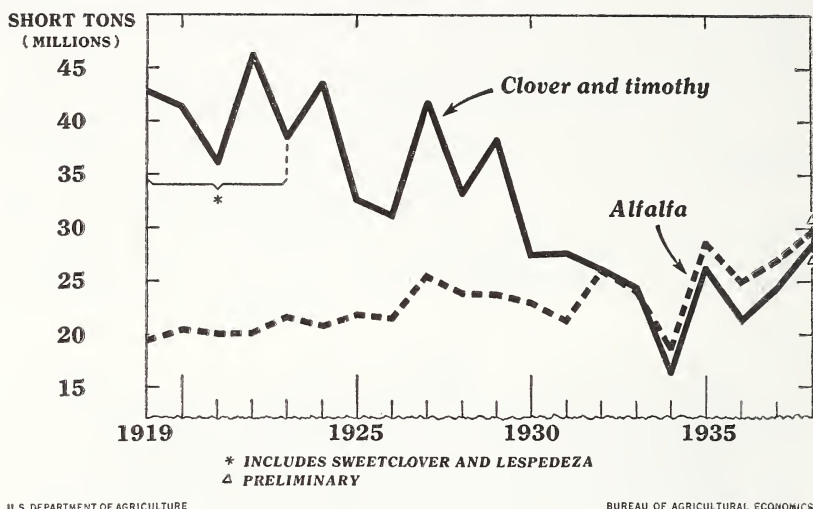
TABLE 22.—Forage crops in 1937

Crop	Acreage	Production	Farm value ¹
	<i>1,000 acres</i>	<i>1,000 tons</i>	<i>1,000 dollars</i>
Alfalfa.....	13,787	27,056	282,735
Clover and timothy.....	19,481	24,335	237,023
Sweetclover.....	649	776	3,888
Lespedeza.....	2,036	2,107	22,060
Soybean, cowpea, and peanut-vine hay.....	7,407	7,748	81,664
Grains cut green for hay.....	4,641	4,702	41,143
Miscellaneous tame hay.....	6,791	7,061	58,253
All tame hay.....	54,792	73,785	726,766
Sweet sorghum for forage and hay.....	2,996	4,378	29,114
Wild hay.....	11,552	9,302	52,277
All hay.....	69,340	87,465	808,157

¹ Production figures were multiplied by the Dec. 1, 1937, farm price to obtain farm value as of that date.

There have been important changes in the acreage of several kinds of tame hay in recent years. The acreage of alfalfa hay is now 12 percent above the 1927-37 average; clover-timothy acreage, on the other hand, is about the same percentage below average. For production of clover and timothy, and alfalfa, from 1919-38, see the following chart. Acreages of soybeans for hay in the Corn Belt and of various legumes in the South have greatly increased in recent years.

Hay: Clover and Timothy, and Alfalfa, Production, 1919-38



The present tendency is to increase the acreage of hay crops, and the soil-conservation program is encouraging the use of additional acreage for legumes. A large acreage of both grasses and legumes will, therefore, be available for hay production in 1939, if there is no extensive drought, and supplies are likely to continue to be ample considering the number of livestock to be fed. Looking further ahead, the outlook is that hay requirements will increase for several years because of the present rather general tendency to increase the number of cattle.

Alfalfa, clover, and timothy have for many years constituted the bulk of all tame hay produced, but the percentage of the total made up of these kinds of hay has been gradually declining during the past 15 years, as shown below:

Percentage of total production of tame hay made up by alfalfa and clover and timothy

Year:	
1923	79.9
1924	81.6
1925	80.9
1926	78.5
1927	80.8
Average	80.34
1928	79.1
1929	82.0
1930	78.6
1931	73.5
1932	72.6
Average	77.16

*Percentage of total production of tame hay made up by alfalfa and clover
and timothy—Continued*

Year—Continued.

1933	73.0
1934	63.9
1935	70.2
1936	72.8
1937	69.6
Average	69.90

The figure for 1923 includes small quantities of sweetclover and lespedeza.

Minor hay crops, production of which has been increasing during the past 15 years, include soybeans, cowpeas, and lespedeza.

ALFALFA

During the last 20 years the importance of alfalfa as a hay crop has been growing rapidly in comparison with other hay crops. It is now the most important with respect to production and farm value and for this reason will be given special attention.

The total acreage of alfalfa in the United States has increased from 9 million acres in 1920 to slightly over 14 million acres in 1936. The acreage has decreased slightly, however, during the last 2 years, that of 1938 being estimated at 13,675,000. Although droughts during the period 1930–36 thinned alfalfa stands in the drought areas, the present tendency is to increase acreage. The alfalfa hay crop over the last 10 years has ranged from roughly 19 million tons in 1934, a year of short production, up to 27 million tons in 1937. The annual production is usually about 25 million tons and during the past 4 years has exceeded that of clover and timothy hay by $2\frac{1}{4}$ to $3\frac{1}{2}$ million tons.

Alfalfa is grown throughout most of the United States, as shown in the distribution map. The chief producing State is California, which has produced just under 3 million tons a year as an average for the last 10 years. Among the other leading alfalfa States are Idaho and Nebraska, each having an average output of about 1,888,000 tons. Other States producing over a million tons annually are Colorado, Kansas, Minnesota, Iowa, Michigan, Montana, Utah, and Wisconsin.

Alfalfa cannot be grown successfully on acid soils and is most easily cured in a climate that is not rainy during summer. Consequently the crop is most extensively grown in the West, under irrigation, and in the subhumid parts of the Great Plains. It also does fairly well in the limestone regions of the East, where its culture has increased rapidly in recent years. Even on limestone soils in humid areas, liming is generally essential to the success of the crop.

The weighted-average farm prices of alfalfa hay in recent years have been as follows:

Year:	Average price per ton
1932	\$6.99
1933	8.42
1934	14.43
1935	8.53
1936	12.35

Alfalfa is used principally as a feed for dairy cows, but it is also an important foodstuff for other domestic animals, including horses, beef cattle, sheep, rabbits, and poultry. It is a good source of protein of high quality, as well as of carotene and calcium. These characteristics, combined with high yields, make it a valuable crop for hay and forage. The crop is also extremely valuable from the standpoint of crop diversification and soil enrichment. The practice of storing some forage crops as silage has been increasing in the dairy sections because it eliminates the loss in quality which often occurs when hay is field-cured. This is especially important for first-cutting alfalfa and the practice may become of increasing importance during the next few years.

Alfalfa meal is the chief industrial product made directly from alfalfa. It is prepared by grinding or cutting alfalfa hay to rather coarse particles. It is used to a limited extent in the preparation of carotene for human and animal use, but its main outlet is in animal feeds. The bulk of alfalfa meal is made from field-cured hay delivered to the mills in bales, but in recent years increasing quantities have been made from alfalfa artificially dried in belt-conveyor or rotating-drum driers. The advantages of grinding or cutting alfalfa hay into so-called meal are that there is less loss in feeding, the shipping charges are less for the ground product in bags than for baled hay, and the meal may be used for the preparation of mixed feeds. Some alfalfa mills are operated in connection with mixed-feed plants, but the greater part of the alfalfa meal produced is shipped to mixed-feed plants or is sold for feeding without mixing.

For the preparation of special-purpose feeds, alfalfa-leaf meal is a high-quality ingredient. The discarded stem meal then becomes a byproduct, used in low-grade feeding mixtures.

The commercial production of alfalfa meal amounted to about 312,000 tons in 1936, and 351,000 tons in 1937. During the past 5 years, production averaged 255,000 tons with an approximate value of \$5,600,000.

The area of alfalfa grown for seed has been slightly under half a million acres in the last 3 years. The average was 426,000 acres over the period 1928-32. The average yield of alfalfa seed is from 1½ to 2 bushels to the acre. The total production of alfalfa seed in the country has been about 900,000 bushels in the last few years. The alfalfa seed crop in 1937 amounted to 943,900 bushels, and the average for the years 1927-36 was 926,000 bushels. The principal alfalfa-seed producing States are Arizona, California, Minnesota, Utah, Oklahoma, Kansas, Nebraska, Idaho, and Montana.

The gross farm income from alfalfa seed amounted to nearly 9 million dollars in 1936, and to slightly over 12 million dollars in 1937. The weighted-average prices of alfalfa seed as received by producers have been as follows for recent seasons:

Year:	Average price per bushel
1932.....	\$5. 52
1933.....	6. 07
1934.....	9. 96
1935.....	7. 89
1936.....	11. 89
1937.....	13. 79

PRESENT RESEARCH

Present research is concerned to a large extent with agricultural problems, but emphasis is also placed on nutritional and vitamin studies owing to the great importance of alfalfa as a feed or as an ingredient of mixed rations for a variety of livestock. Investigations dealing with drying and curing methods are also of considerable importance. The following specific types of research activities have been disclosed by the Survey:

Agricultural research.

1. Comparative studies of the yields and economic qualities of standard and new or regional varieties and strains, including lines of common and hairy Peruvian alfalfa.

2. Development of disease-resistant strains by breeding and selection and testing for productivity, cold and wilt resistance, or other characteristics of economic value.

3. Studies on the influence of variety, soil type, soil amendments, cultural practices, stage of maturity, age of stands, and harvesting methods on the general quality and protein content of alfalfa.

4. Experiments on the production of crops of high protein content and high energy value.

Curing and processing.

5. The effects of different conditions of field curing, artificial drying, baling, and storage on the quality and feeding value of alfalfa and the losses of dry matter, nutrients, and vitamins in the preservation of alfalfa through curing and storage. These are all being studied but need much more attention.

6. The efficiency of the trench silo for preservation of alfalfa and other forage, as measured by chemical means and by the utilization of the nutrients by cattle; also the development of new methods for making ensilage by addition of acids and carbohydrates.

Nutrition.

7. Studies on the nutritive value of various grades of alfalfa and alfalfa derivatives for growing chicks and poultry; the efficiency of alfalfa hay as a sole ration for dairy cattle and its relation to sterility; the influence of alfalfa on the vitamin D potency of milk; efficient mixtures of protein feeds including alfalfa meal for growing and fattening swine and other animals; the biological value of the various proteins of alfalfa; the effects of cottonseed meal and cottonseed hulls versus those of white corn and alfalfa hay on the quality and palatability of beef; the effects of dried and preserved alfalfa and other forage on the nutritive value of milk; and the effect of sulfur dioxide in the atmosphere on the production and nutritive value of alfalfa.

8. Investigations on the general factors affecting the vitamin content of alfalfa and the stability of the carotene of alfalfa meal and of vitamin A from added cod-liver oil in mixed rations.

Fundamental chemical research.

9. Quantitative studies on occurrence of vitamin A, carotene, and other food supplements in alfalfa.

SUGGESTED RESEARCH

The lines of investigation which have been suggested for research are in many instances merely amplifications of work now in progress. This does not necessarily mean a duplication of research effort, but a more completely developed program of coordinated fundamental research that could advantageously be undertaken. Such an amplified program is essential for the ultimate solution of many practical problems, e. g., prevention of denaturation of protein during the curing process. Emphasis is placed on nutritive values, vitamin studies, and general composition.

The following supplemental investigations have been suggested:

Agricultural research.

1. A study of the general factors and conditions of growth environment which significantly influence the composition of alfalfa and its products, including the mineral content, especially of lime and phosphorus.

2. Other studies would relate to the protein content of alfalfa cut at progressive stages of growth or maturity and improvement of the productivity and quality of alfalfa by breeding methods.

Curing and processing.

3. A thorough study both in the laboratory and on an engineering scale of hay-curing methods, including natural and artificial curing and drying.

4. A detailed study of methods of preserving alfalfa as ensilage. A number of methods are practiced, the advantages or disadvantages of which have not been adequately determined; further research is indicated in this field.

Nutrition.

Nutritional problems associated with rations consisting principally or solely of alfalfa. The nature of each problem is dependent to a considerable extent on the particular feeding purpose, the type of animal being fed, and economic considerations.

5. One important problem is the relation of harvesting methods, handling, and storage or processing operations to the vitamin content and nutritional value of alfalfa.

Fundamental chemical research.

6. A complete chemical inventory, including both inorganic and organic constituents, of alfalfa of different varieties grown under widely varying soil and climatic conditions.

7. Further fundamental work on the accurate determination of vitamin G and the occurrence of carotene or other yellow pigments in alfalfa.

8. The utilization of alfalfa as a source of pigments, vitamins, and carotinoids, obtained by extraction and processed for human or animal consumption.

OTHER HAY AND FORAGE PLANTS

CLOVERS AND TIMOTHY

Clovers are important in every agricultural region of the United States. Depending upon the species, the crop may be utilized for pasture, hay, or soil improvement either when produced alone or in

association with grass. Red, alsike, and white clovers are major legumes in the Corn Belt and northeastern dairy regions and throughout the northern irrigated intermountain and Pacific Northwest States.

The intrinsic value of many of the winter annual species utilized for winter and spring grazing in the Southern and Pacific States, particularly crimson, low, least hop, white, and Persian clovers, is just beginning to be fully recognized.

Throughout the Great Plains, from Texas to the Canadian border, and in the western Corn Belt States the acreage of sweetclover is rapidly increasing.

Available hay-production figures are inadequate to represent the value of clovers, since the crop is more widely used for pasturage and soil improvement than for hay.

In 1937 the farm value of red, sweet, and alsike clover hay and seed approximated \$269,000,000, not to mention many other clovers for which statistics are not available.

Only a small proportion of the clover crop is harvested for seed each year. The production of red clover, alsike clover, and sweet-clover seed had a total farm value during the last 10 years ranging from 9 to 30 million dollars.

Timothy hay formerly was a cash crop of some importance, having a rather extensive market in the feeding of city horses. In the last 25 years, however, the number of horses in the United States has been cut in half, and the city horses have virtually been wiped out of existence. As a result, the old market for timothy hay has nearly disappeared. There are still quite extensive areas of timothy being grown, and a considerable volume of this hay is coming on the market each year.

COWPEAS

Cowpeas are the principal annual legume in the Cotton Belt, as soybeans are in the Corn Belt. Both crops are grown in the intervening Corn and Winter Wheat Belt. Cowpeas are at once a feed crop, a cover crop, and a leguminous soil builder.

The acreage of cowpeas alone in recent years has ranged from 2 million acres in 1931 to 3½ million acres in 1937. In addition to the latter figure, it is estimated that about 2 million acres of cowpeas were interplanted with other crops.

A typical picture of the utilization of the crop is that for the crop year 1935, when there were 9,663,000 acres of cowpeas grown for peas, grazing, and other purposes. Out of this acreage were gathered 5,816,000 bushels of peas, the disposition of which was as follows: For feed for livestock, 1,379,000 bushels; for seed, 1,344,000 bushels; used in the farm home, 414,000 bushels; sold, 2,679,000 bushels. The average price per bushel received by the producer was \$1.56.

The weighted-average prices for recent seasons have been as follows:

Season:	<i>Average price per bushel</i>
1933-34.....	\$1. 32
1934-35.....	1. 48
1935-36.....	1. 56
1936-37.....	1. 72
1937-38.....	1. 34

Cowpeas brought farmers a gross farm income of \$4,228,000 in 1936, and \$3,399,000 in 1937.

SOYBEANS FOR HAY AND FORAGE

Soybeans as a seed crop and research bearing upon their production and utilization are discussed in the section on Oil Seeds and Crops.

During the last 10 years there has been a rapid increase in the production of soybeans for hay and forage as well as for beans. Out of a total of 2,439,000 acres in 1928, 1,860,000 acres were not harvested for beans and out of a total of 6,982,000 acres in 1937, 4,645,000 acres were not harvested for beans. While there has been an increase within that period of 303 percent in the acreage harvested for beans, there has also been an increase of 150 percent in the acreage of soybeans for other purposes.

A large part of the present research on forage crops being conducted in State agricultural experiment stations and agricultural colleges is concerned with the production and use of soybeans for hay and forage. Such research and suggested research along the same lines are included under research on hay and forage crops in general.

LESPEDEZAS

The lespedezas that are of agricultural importance were introduced from the Orient. This group of leguminous plants is well adapted to the southeastern Atlantic and Gulf States, and west to Oklahoma, and certain varieties will grow as far north as the central Corn Belt. The two chief annual species make a growth of 6 to 12 inches in a season, while the perennial species, *sericea*, after establishment, may grow from 3 to 4 feet in a season. They are warm-weather plants, and the annuals are killed by the first frost in the fall. The crop is a prolific seeder, and the annuals are enabled thus to perpetuate themselves from year to year. The annual varieties are excellent for soil improvement and pastures, and good hay can be made when there is sufficient growth to make harvesting possible. They have a great deal of merit in the region mentioned as soil reclamation and conservation plants, their thick mat of growth preventing soil washing.

The area harvested for lespedeza seed in 1937 totaled 484,000 acres, and the output of seed amounted to 99 million pounds, with an estimated farm value slightly under 5 million dollars. In 1938, 703,000 acres produced 189.2 million pounds of seed.

The principal use of lespedeza is for pastureage, being grown either in combination or in rotation with other pasture plants. It is also grown for hay, approximately 2 million tons of the crop having been harvested in 1937 from about 2 million acres. In 1938, the acreage increased to 2,428,000 and the tonnage of hay to 2,758,000. The quality of this hay compares favorably with that of alfalfa.

VELVETBEANS

Velvetbean production is confined largely to the States of Georgia, Alabama, Mississippi, Florida, South Carolina, and Louisiana, although the crop can be grown successfully throughout most of the Cotton Belt. The crop is well adapted to the sandy Coastal Plain soils of the South Atlantic and Gulf States. The total area in velvetbeans in 1937 was about 2 million acres.

The farm value of this crop has ranged during the past 4 years between 10 and 13 million dollars, although this is a nominal figure, since velvetbeans are not sold to any large extent.

The principal use for velvetbeans is as a grazing crop for livestock, particularly cattle and hogs, although the crop is also of considerable value for soil improvement. Very little use is made of velvetbeans as hay because the long vines make handling difficult. Velvetbeans contain a slight amount of poisonous ingredient and have not been found satisfactory for human food.

PRESENT RESEARCH

Many researches are now devoted to hay and forage crops in the various experiment stations and Government organizations, and many problems of cultural conditions, curing, preservation, quality, nutritive value, and feeding requirements of the numerous species of plants are being studied. Because many of the research projects reviewed are similar in character, they are, for convenience, grouped together under the following class headings: Agricultural research; curing and processing; nutrition; and fundamental research. With the exception of alfalfa, which has been covered in a previous section, the hay and forage crops are considered as a group.

Agricultural research.

This type of research pertains to various problems of forage production, including:

1. Breeding and improvement experiments on all the more important grasses, clovers, and miscellaneous legumes.
2. The use of soil amendments and their influence on forage yield and composition.
3. With special strains of *Lespedeza sericea* or other perennial lespedeza, studies on the effects of environmental factors on the general structure and tannin content or other related qualities of the plants.
4. The production of grasses and legumes of special composition, including those having a high protein content and high energy value, and the various factors affecting production of these and other prairie hays. This is an important part of this research.

Curing and processing.

5. The harvesting, curing, and processing of forage crops. These steps are of utmost importance in the preparation of feeds having the maximum nutritive value, and under this heading are included studies on harvesting methods at different stages of maturity, shrinkage, artificial and efficient air drying, and storage methods for either loose or baled products.

6. The storage of forage crops. This has received considerable attention. Studies include mow and stack ventilation and the spontaneous ignition of hay, the relation of harvesting, drying, and storage to the vitamin and carotene contents, and the feeding value of forage artificially cured under different conditions.

7. Investigation of methods for making ensilage from various forage crops with regard to both processing and nutritional research. This includes studies on different types of silos, methods for making ensilage using phosphoric and other acids, and the mixing of such other commodities as cull potatoes and apples.

Nutrition.

8. Investigations on the quality and nutritive value of cured hay, ensilage products, pasture grasses, and ground legume meals, such as alfalfa, in feeding experiments with all types of farm animals.

9. The replacement value of forage crops in various feed rations and the biological value of various proteins of the different forage commodities. Little actual work has been done on this problem, although it has received careful consideration.

Fundamental research.

10. Studies concerned primarily with the composition of forage crops at various stages of maturity and the effects of different soils, fertilizers, lime, etc., on the mineral and organic content of the plants.

11. Study of the hemicellulose and lignocellulose contents of the various hays and forage crops, as well as the nature of decomposition products resulting from fermentation, oxidation, and other chemical processes.

12. Investigation of factors responsible for hydrocyanic acid in Sudan grass, sorghum, etc., and also of the effect of colchicine on the tannin content of lespedeza.

13. Investigation of the carotene, xanthophyll, and vitamin contents, as well as changes in protein and protein denaturation, as affected by the methods of harvesting and handling. These need much more intensive study.

14. Physical measurements, such as the relative weights of leaves, heads, and stems at varying stages of maturity, and the development of improved methods for measuring the color of hay.

SUGGESTED RESEARCH

Agricultural research.

Of importance are—

1. Better management and improvement of pastures and investigations on the influence of climate, variety, soil fertility, and other factors upon the physical and chemical character of the proteins, starches, and other nutritional constituents of the principal hay and forage crops.

2. Basic research to establish a firm foundation for investigations on curing, preservation, storage, feeding, and other disposition of the hay crops in relation to the dairy and other animal industries, which are vitally dependent upon hay and forage production.

3. The selection of plants for pasture or silage having the most desirable composition for specific feeding requirements of farm animals.

Curing and processing.

The need for improved methods of curing hay is becoming more acute, especially in the wet seasons, since emphasis is being placed on the increased use of hay crops for soil protection purposes and larger yields are being obtained by improved fertilization practice.

4. Research on the economic aspects for farm use of mills for chopping hay, artificial drying of hay, and ensiling of hay.

Nutrition.

5. Further research is needed on the unidentified essential nutritive factors in forage plants at various stages of their development and in the forage preserved as hay and silage. All attempts to rear

certain types of farm animals without pasture, hay, or silage have led to complete failure and apparently have induced disease symptoms, including paralysis and muscular dystrophy. Research is suggested on:

6. The relative nutritive value of various leaf proteins in relation to milk production by dairy cows.

7. Intensive studies of the vitamins other than vitamin A that occur in forage plants, in order that the knowledge regarding them may be at least as complete as that already acquired on vitamin A.

8. Nutritional deficiencies resulting from poor quality of proteins or inadequate quantities of minerals in individual forage plants, harvested at various stages of growth. This information is needed in order that deficient forage plants may be properly supplemented in the ration, either with other forage plants or with concentrates.

9. The unidentified dietary factors, present in fresh green pasture grasses but lacking in hays and silages, which promote reproduction and lactation in cattle. Pastures furnish about one-half of the total feed for farm animals and deserve much more attention with regard to their value in animal nutrition. It may be possible to extend the utilization of grasses and other green feedstuffs by making from them preparations which are useful in human nutrition or in human or livestock therapeutics.

10. Extension of the uses of timothy, one of the most important hay grasses, by including it in mixed ensilage rations.

Fundamental research.

11. Further and more extended investigations relative to the vitamin and mineral contents of hays with the purpose of promoting wider usage and more specific adaptation of the foodstuff for nutrition. Much progress is being made in vitamin research; and the most modern methods should be applied to hays. The use of grasses and other forage plants as sources of plant pigments, vitamins, and carotinoids by extraction should be studied with a view to processing for human and animal consumption.

12. Investigation of the losses and chemical changes which take place in hay during curing and storage. An appreciable loss of nutritional value invariably occurs between the time the green hay crop is cut and that of consumption by animals. A considerable minimization of the losses and unfavorable chemical alterations in hays could doubtless be accomplished by the aid of the fundamental knowledge so obtained.

FOREST PRODUCTS

The problems of utilization of forest products are broad and complicated. The principal reasons for this situation are as follows:

1. The uses of forest products are numerous and varied—from beams to toothpicks, from telephone poles to rayon, from fence posts and railroad ties to furniture and newsprint paper.

2. The requirements of the various uses must be met both by proper selection from the wide variation in species properties and by artificial modification of these properties.

3. The markets for forest products are highly competitive, and they compete mainly with other structural materials from nonrenewable resources, such as concrete, ceramics, metals, and plastics. The substitution of other materials for wood, developed through scientific

research, has resulted in a consistent and substantial loss of markets for forest products since 1909.

Utilization problems are further complicated by the fact that the quality of the wood available for use is constantly changing as the virgin timber in certain localities is cut out and either local second growth or other species from other localities are substituted. While it may be said that there is a potential scarcity of virgin timber, there is unquestionably a tremendous supply of low-quality second growth which under current utilization practices and in the face of consistent improvements in competitive materials is not marketable.

Aside from the problem of maintaining markets for the ordinary uses of wood, forestry is confronted also with the problem of utilization of tremendous quantities of wastes, not only logging, milling, and manufacturing wastes but wastes in low-grade lumber and in whole species of innately poor quality. The waste problems are different from those of some other crops in that the wastes are largely of the same substance as the product—they are wood and are waste on account of unfavorable size or quality.

The economic importance of forest-products utilization is shown by the fact that the forest industries of the United States are now giving direct support to 6,000,000 people. This is aside from the fact that farm woodlands contribute directly toward the support of 2,500,000 farm families. Altogether wood-utilization problems are concerned with the disposal of timber crops from nearly a half billion acres of forest land, with the success of industries valued at 10 billion dollars, and the consumption of products valued at 3 billion dollars annually.

The detailed survey of forest-products research will be taken up in seven separate reports on distinct phases of the general problem, namely:

1. Wood chemistry.
2. Pulp and paper.
3. Timber mechanics.
4. Modification of wood properties.
5. Timber physics.
6. Relation of growth, structure, and properties.
7. Mechanical conversion methods.

WOOD CHEMISTRY

Under this division of forest products research is included (1) fundamental research on the chemical composition and colloidal properties of wood and wood components and on the location and distribution of the chemical components—chemical structure—of wood, and (2) applied research, originating largely from (1), on all chemical utilization methods except pulp and paper making.

The main part of these researches is applicable to the problem of waste-wood utilization: Logging wastes, 52 million tons; milling wastes, 22 million tons; secondary manufacturing wastes, 12 million tons; and over 4,000,000 tons of solids in pulping liquors annually. Most of these wastes have no value and are nuisances and hazards. They also are mostly of a size and quality that limit practical utilization to chemical methods. The wood-distillation industry is the only one now utilizing any considerable part of this waste, about three-

fourths of a million tons in 1937, and this kind of utilization now has only about one-half of its former value on account of the manufacture synthetically of the main wood-distillation products.

Much of the fundamental information is also applied in research and practice in other fields of wood utilization (pulping, impregnation, drying, and modification of properties), the economic status of which is covered in other parts of this report.

PRESENT RESEARCH

Fundamental research.

Industrial laboratories and universities as well as governmental agencies have been carrying on considerable fundamental research in the chemistry, chemical structure, and physical chemistry of wood, along the following lines:

1. Comparative chemical composition of species, heartwood and sapwood, in terms of groups and complex constituents, methoxyl, acetyl, extractives, cellulose, pentosans, lignin, uronic acids, and, more recently, holocellulose.

2. The manner in which these constituents are chemically combined in the original wood.

3. The location of these constituents in the microstructure such as the distribution of the lignin in the cell-wall layers.

4. The structural units of the cellulose layers, fibrils, fusiforms, etc.—how they are arranged and how they affect the properties.

5. The chemical composition and constitution of the complex constituents in (1), especially the lignin, holocellulose, and extractives.

6. The effect of decay on the chemical composition of wood.

7. The fermentation of the carbohydrate constituents of wood.

8. Molecular size and shape of cellulose and lignin ultimate particles.

9. Capillary structure of wood—microscopic and submicroscopic.

10. Colloidal characteristics of wood: Adsorption of vapors and selective adsorption from solutions; the mechanics of swelling and shrinking; the effect of moisture content on electrical properties; diffusion of moisture through wood; true specific gravity of wood substances.

Applied research.

This includes two classes of research (1) the technology of existing chemical utilization industries and (2) the development of methods suggested by the results of the fundamental researches.

11. Recent research in hardwood distillation—confined largely to the development of improved refining methods for the production of acetic acid to better meet the competition of the synthetic product. (Resinous wood distillation is covered in the section of Naval Stores.)

12. Research in wood hydrolysis for the production of sugars and alcohol—confined largely to application of German methods and their modification for use with United States species.

13. Studies of the action of thermophilic bacteria on partly delignified wood.

14. Production of plastics from wood by various methods of pre-treatment and plasticizing. (This work is closely related to that described under Plastics in the section on Agricultural Wastes.)

15. The hydrogenation of lignin which has just developed from the fundamental to the applied research stage through the discovery that

high yields of new chemical products can be obtained by hydrogenation. (See Lignin in the section on Agricultural Wastes.)

16. Research on pulp liquor wastes. This has been confined largely to sulphite process liquors, and has included work on the production of vanillin, tanning agents, road binders, cement setting agents, storage battery "expanders," etc. (See also section on Pulp and Paper, as well as the section on Lignin referred to above.)

17. The applied research on the prevention of shrinkage, developed from the fundamental colloidal researches, which is reported in the section on Modification of Properties.

SUGGESTED RESEARCH

Fundamental research.

The recent fundamental researches on wood seem to be very comprehensive in the mere listing of fields of work, but few of these fields have been thoroughly investigated and in most of them the work has been only of a preliminary nature. In researches of this kind, also, a field may seem to be for a time very thoroughly explored but advances in current knowledge and technique in other related fields may soon show the way to more complete information. The sections of this report dealing with Fiber Crops and with Agricultural Wastes, for instance, will be found to be exceedingly suggestive, because of the many close relationships in composition and structure between wood and other agricultural materials. Work in these closely related fields covers so wide a range of interests and of industrial developments that special effort toward coordination seems imperative; the mere physical volume of the published research and the dispersion of those publications through scores of journals in half a dozen languages, have had the effect of hindering that wide knowledge and utilization of new techniques which is so desirable.

In view of the values already obtained from fundamental research, especially by discoveries leading directly to applied research, as in wood plastics, lignin hydrogenation, and antishrinkage treatments, the wider exploration of this field should lead to continued advances in chemical conversion and modification of properties. In general, the fundamental problems in the chemistry and physical chemistry of wood, like those of cotton or of cornstalks or straw, should be attacked with all the ultramodern devices and techniques that science can offer. More specific suggestions for research in comparatively narrow fields are as follows:

1. Although the research on the constitution of lignin has already yielded several promising methods for its commercial utilization, its actual composition is still unknown. Research on this subject should be continued in broad scope since the amounts of waste lignin are so tremendous that many different kinds of products must be made from it to utilize any considerable proportion of the total available. (See the subject of Lignin in the section on Agricultural Wastes.)

2. One specific field in which only the most fragmentary work has been done is the decomposition of wood at temperatures below the ordinary destructive distillation point of 275° C. The small amount of information available on this subject indicates the possibilities of old and new volatile distillation products with a residue suitable for gas generator fuel, for hydrogenation, or for plastics. This project should also include special attention to long-continued, low-tempera-

ture treatments similar to a severe drying, with a determination of effects on physical properties.

3. The recent discovery of methods for isolation of the completely delignified carbohydrate fraction of the wood (holocellulose) now makes possible the study of the hemicelluloses in toto, with all their constituent groups intact, and this field should be further explored to determine the chemical and structural relationships of the hemicelluloses to the other wood constituents. (See the subject of Hemicellulose in the section on Agricultural Wastes.)

4. The amount and composition of the extractives in wood (materials such as resins, dyes, tannins, and gums, removable by neutral solvents) have been determined in only a few species. Redwood, western red cedar, and black locust are especially promising for further research in this field.

5. Aside from its tannin content little is known about the chemical composition of bark. Since bark constitutes a considerable proportion of woods and sawmill wastes, its chemical composition should be explored just as thoroughly as that of wood.

6. Continuation and expansion of physicochemical investigations, especially: (1) Steady-state moisture diffusion; (2) concurrent viscosity and hydrolysis measurements on holocellulose; (3) correlation of diffusion, osmotic pressure, and ultracentrifuge measurements on holocellulose fractions; (4) heat of wetting and rate of swelling of wood in various liquids; (5) determination of swelling pressure of wood in various liquids.

Applied research.

A list of specific projects in applied research on chemical conversion cannot be expected to remain complete for any considerable period because it requires additions from time to time as new discoveries are made in fundamental research. A few years ago wood plastics would not have appeared in this list, and only within a year has the fundamental research on the constitution of lignin reached a stage where a part of it, hydrogenation, could be transferred to the applied group. Results obtained from the proper prosecution of the suggested fundamental projects may require the addition of new applied projects in a short time. At any rate, the utilization of enormous quantities of waste wood will depend largely on the outcome of applied research of the kind now outlined or as modified by future fundamental research.

7. Investigate other methods of making plastics from wood, especially the effects of mechanical treatments and of other plasticisers.

8. Expand the plastics research to include the consolidation of wood particles, such as sawdust, with binders to produce a material more like artificial wood.

9. Take up the hydrogenation of lignin with a view to commercial application, including (1) most efficient conditions for hydrogenation-temperature, pressure, and catalysts; (2) specific application to most readily available lignin wastes, different kinds of pulping liquors, and various species; (3) the composition of the products from various sources and methods; and (4) the properties of the new products to determine their commercial uses.

10. Hydrolysis of wood for the production of sugars and alcohol only is apparently not profitable under present conditions, but the use of the lignin residues for plastics or other products may make

the combination process practical. A correlated attack on the combination process is suggested. Here again a very similar problem is encountered in the treatment of agricultural wastes.

11. The distillation of hardwoods, the only chemical industry now using considerable quantities of waste wood, has been operating at decreasing capacity for several years, and in order to increase the utilization of beech, birch, maple, and oak wastes the technology of this industry must be improved. New methods of heating the retorts, pretreatment of the wood with chemicals, better utilization of wood tar, and new uses for the charcoal have been suggested as lines of attack.

PULP AND PAPER

The pulp and paper industry annually produces products to the value of more than a billion and a half dollars, has an investment in equipment, land, buildings, etc., of approximately a billion dollars, gives employment to nearly 300,000 persons, and pays out in wages and salaries more than 300 million dollars annually. The industry is based largely upon the use of wood, which comprises about 85 percent of the fibrous raw materials. In addition to the domestic industry there is imported annually into the United States over 200 million dollars' worth of paper and paper base stocks, which include pulpwood and wood pulp. These represent potential additional outlets for our own forest crop and additional investment opportunities.

The annual consumption of paper has now reached about 16 million tons, and this use trend, if continued, indicates that by 1950 it will reach 24 million tons. This will require approximately 25 million cords of wood or the equivalent raw materials.

PRESENT RESEARCH

Present and past research on the pulp and paper field has included the improved and increased utilization of specific species with a constant effort to broaden the species base, methods to improve the quality and properties of pulp and paper, and means for elimination of waste. Research along these lines has been under way at several Government laboratories and a number of university laboratories, as well as several large privately financed laboratories and mill research staffs. Federal and State agencies are concerned largely with broadening the species base, and other problems of general interest to both industry and the public. Private research is concerned with improved technology and with broadening the field of use of wood-fiber products.

SUGGESTED RESEARCH

The following major lines of research in pulp and paper are suggested:

1. Comprehensive evaluation of the 90 United States species having potentialities for pulp and paper production using standard pulping processes and conversion into standard types of paper and boards. This investigation will supplement preliminary work which has already been done mostly by Government agencies.

2. Fundamental research on the determination of effects of machine variables, fiber-processing variables, and pulping variables which affect the quality, character, and utility of pulps and papers, in for-

warding objectives under 1. (See also the discussion under Cellulose in the section on Fiber Crops.)

3. Study and improve the chemical and physical characteristics of pulps which are of importance in their conversion to chemical cellulose and such derived products as rayon, films, and lacquers. (See Cellulose.)

4. Investigate methods for the elimination, utilization, or control of waste in pulp and paper manufacture which now amounts to over 3 million tons annually and consists largely of fibrous wastes, lignin, carbohydrates, fats, and protein material which may have tremendous use value.

5. Develop modifications of present pulping processes or new methods of pulping, both mechanical and chemical (including continuous processes), which will increase yields, improve and broaden the utility of fibers now used, or permit use of new species for a much wider industrial application.

6. Study the fundamentals of pulp bleaching.

7. Investigate possibilities of using low-grade base stocks for higher grade papers, including coatings for mechanical pulp papers and methods of utilizing low-grade woods in higher grade products.

8. Develop means for controlling pitch in paper-making operation to promote use of resinous woods by acid-pulping processes.

9. Fundamental studies of the dyestuffs, fats, and other wood extractives which affect the pulping and paper-making operation or may offer improved utilization of byproducts.

10. Study of deinking and printing processes as measures of conservation and reuse of old papers.

11. Investigate the pulping of exotic species to supplement native raw materials for pulp and paper.

12. Comprehensive study of the use requirements of various papers and paper products for the more effective use of existing raw materials and the development of new outlets for pulps; this work should include the development of adequate testing and evaluating methods.

TIMBER MECHANICS

This is the broad term applied to fundamental research on the mechanical properties of wood, on the principles underlying its behavior under stress, and on the strength of structures and commodities made of wood. Timber-mechanics research is concerned with how strength and related properties are affected by such factors as the minute structure, moisture content, and defects, and by various processing treatments; with how the formulas of mechanics must be modified for application to wood; with the establishment of grading rules, specifications, and working stresses; and with the design and fabrication of structures, structural units, and other commodities, including the design of improved joints and fastenings employing glue, nails, bolts, screws, and other devices. The work thus covers all phases of forest-products research relating to behavior under stress and the resistance to forces. Studies of fiber containers are also included.

Some of the more important economic considerations of this research are: (1) Sixty percent of all lumber is used for building and construction purposes; (2) wood is the cheapest raw material now known

for the construction of low-cost houses; (3) domestic farmers constitute the largest lumber-consumer group, using one-third of the lumber cut; (4) wider markets for low-grade material and smaller sizes have resulted from significant developments in the fabrication of laminated structures, which also have other salient advantages; (5) one-eighth of all lumber and 2,800,000 tons of solid and corrugated fiberboard are used for shipping containers; (6) the faulty design of fiber containers results in an estimated annual 50-million-dollar damage to products during transit (including concealed and unreported damage).

PRESENT RESEARCH

Numerous research projects by industrial and agricultural agencies in the field of timber mechanics have been undertaken under one or more specific headings. They are listed as follows:

1. Fundamental research on mechanical properties, including the evaluation of some 20 properties, such as hardness and modulus of elasticity, on 164 species of wood and the appraisal of the effect of certain factors on strength. These data provide a means for comparing woods, for calculating the strength of wooden members, for establishing safe working stresses for the design of wooden structures, and for furnishing a basis for substituting species.

2. Improvements in structural design and fabrication of wood structures and structural units, including research on joints and fastenings, laminated construction, and building construction. Research in improving joint construction has concerned some phases of nailing, screws, lag screws, bolts, and modern metal connectors, the latter opening entirely new fields to wood construction. Laminated-construction research has been confined principally to the wooden arch. Building-construction research has centered around the solution of problems relating to the use of wood in different forms, the relative merits of different construction details, and the exploration of entirely new and novel assembly and construction methods contemplating the benefits of some greater degree of factory economy.

3. Basic research on fiber shipping containers is under way, aimed at improving serviceability through a study of the properties of the sheet material and of the fiberboard, and the correlation of these properties with those of the box.

SUGGESTED RESEARCH

Because of the extreme importance of this field of research in relation to construction and practically all other phases of utilization except chemical conversion, the Department has been urged to continue the fundamental work started, and the following suggestions for further research have been made:

1. Low-cost housing is one of the most important problems of the day. Research is needed to develop better and more cheaply maintained structures at appreciably lower costs. The problem involves not only improved modifications of traditional practices, but also the development of new structural systems of known engineering superiority, adapted to factory production of prefabricated units suitable for rapid field assembly. Just what is the final future form that the unit should take is not known at present, but several present promising researches should be extended, covering the use of plywood, fiber-

board, and lumber for the purpose of combining insulation, resistance to weather, and strength.

2. Rural building construction stands in need of aggressive research development. Wood has long been the preeminent construction material for farmhouses and other rural buildings. The buildings on the 6 million farm units of the Nation represent an investment of over 12 billion dollars, about 80 percent of which is wood frame construction.

The higher standards of living, the better buildings required for livestock and farm equipment, and the need of more adequate crop storage facilities all help to confront the farmers with serious building problems. Surveys show that there has been a notable lapse in new construction, the repair and maintenance of present structures, and modernization of homes and other buildings which will entail the expenditure of billions of dollars.

The research contemplates a scientific study of the design, erection, and maintenance of farm buildings, particularly on the better use of local materials and the utility of the various wood and fiber materials on the market.

3. Extended research on joints and fastenings holds the key to improved serviceability of wood in almost every field of use. The wide variation in properties along and across the grain makes the joint strength an ever-present problem. Since a structure or other wood article is only as strong as its weakest joint, research in this field is basic to wood use. The development of the modern metal connector is one advancement in this field. Metal connectors in 1 year accounted for the increased use of over 300 million feet of timber.

4. Research on laminated construction offers one of the most promising methods of effectively extending the utilization of material in low grades and small sizes and is of increasing importance because in the future more of our timber must come from smaller trees. Further development is needed to extend the application to members other than the large laminated arches recently studied.

5. Further research on fiber containers will be necessary to reduce shipping damage and to effect reduced commodity costs to consumers.

6. Fundamental research on plywood: Plywood is becoming of continually greater importance as a structural material. Improvements in gluing technique have expanded its horizons of use. The complicated distribution of an already complex material to form plywood makes necessary the development of new formulas and the establishment of special working stresses for structural use and design.

7. Little or no data on the mechanics of second growth and on four-fifths of the 862 forest-tree species of the United States are available. Data on mechanical properties are fundamental to the more complete understanding and intelligent use of these materials for construction and other uses.

8. Aside from the everyday utility of mechanical properties of wood as determined by standard tests, there is a host of fundamental properties which result from the anisotropic structure that are of ever-increasing importance and on which practically no data are available. These include three Young's moduli, six Poisson's ratios, and three shear moduli, data on which are increasingly needed in the analysis of structure-property relations, in certain design problems, and in calculations of the strength and stiffness of plywood as a plate.

9. Fundamental studies on the effect of temperature in relation to performance in fire and to the effect of preservative treatment, on the effect of fatigue, dead load, and repeated stress, the phenomenon of sag in beams, in relation to moisture content and plasticity illustrate the diverse problems awaiting solution. The development of design formulas, the analysis of stress distribution, and influence of change in form on the stress concentration factors are other phases demanding exploration.

MODIFICATION OF WOOD PROPERTIES

In a large percentage of its uses, wood can be made to give better and more economical service by modifying or improving its properties through treatment with chemicals or other processing.

For example, improvement of resistance to decay and insect attack makes wood practical and economical for many structures where it otherwise would be too short lived. Increasing its fire resistance makes wood a safer material for structures and offers opportunities for reducing the annual loss of life and property due to fires. Decreasing its tendency to change moisture content or to shrink and swell makes wood more serviceable in furniture, millwork, and other uses where changing of dimensions due to moisture changes causes trouble. Gluing makes possible the production of large timbers or wide boards from small material, the production of plywood with its special properties and wide variety of uses, and the manufacture of furniture, fixtures, prefabricated building units, and a host of smaller products that could not otherwise be made or that give better service than if made without glue. Increasing weather resistance by painting or otherwise, protection against wear, as in floor finishing, and changing mechanical properties by impregnation with suitable materials are other examples of important and highly useful property modifications.

The industrial and economic importance of modifying the properties of wood are illustrated by the extent of the present industrial activity or potential developments in the several lines of work involved. For example, the commercial wood-preserving industry has treated an average of nearly 3 billion board-feet of lumber per year during the last 10 years, despite the depression years. This is in addition to the unrecorded amounts of timber treated by "in place" or "home" methods. Much timber is still used without preservative treatment, however, under conditions that favor early destruction by decay, insects, or other wood destroyers. An insignificant number of the possibly 600 million fence posts used each year receive preservative treatment, despite the fact that much longer average life and lower annual costs can be obtained through the proper use of preservatives.

Accurate statistics on the annual cost of keeping homes painted is not available, but it is believed that the cost of the paint alone is of the magnitude of 150 million dollars per year, to which should be added two or three times that amount for the labor involved in its application.

The fireproofing industry is very small because effective fireproofing methods are still far too expensive to find wide use. The great importance of this field of work is in the need that exists for reduction of fire loss in farm and urban structures. Our annual fire loss of over 200 million dollars on wooden buildings and their contents, and of possibly 5 thousand lives, can undoubtedly be reduced by

vigorous prosecution of research in reducing the fire hazard of wood structures through treatment, protective coatings, or better design and construction.

The economic importance of good glues and good gluing cannot be set out in any single figure, but it is illustrated by the fact that the 1937 production of Douglas fir plywood was about 725 million square feet, involving possibly 20 million pounds of glue, a major portion of which was made from soybeans, with smaller amounts of casein and artificial resin glues. The total production of plywood in the United States is probably three or four times as much as the Douglas fir production. Larger percentages of casein, starch, animal, and resin glues are used in the rest of the country than on the Pacific coast. In addition, gluing is very important in the production of furniture, case goods, fixtures, laminated construction, toys, novelties, and a variety of other products.

Much of the trouble encountered in the use of wood products is due to the tendency of wood to shrink and swell as it changes moisture content. The sticking of doors, drawers, and windows in damp weather and their looseness and rattling in dry weather; the warping of table tops, plywood, and furniture of all kinds; the checking of decorative face veneers and of other wood surfaces; the opening of joints between wood members; the development of high stresses in glued products; and a great variety of other troubles encountered in the manufacture and use of wood products are examples of the importance of controlling shrinking and swelling.

There are great possibilities for developing superior hardness, strength, wear resistance, and other properties, when required for special purposes (as in aircraft production), by impregnating wood with suitable chemicals, as is now being done to a small extent by impregnating wood with synthetic resins and then gluing and compressing it.

PRESENT RESEARCH

Considerable research is being undertaken by private and public agencies on the modification of the properties of wood, including the following:

1. Fundamental research on the toxicity of chemicals toward wood-destroying and wood-staining fungi, termites and other insects, and marine borers. This gives basic information that is useful in explaining the effectiveness of preservative treatments, pointing the way to the development of new and better preservatives, and in comparing the economy and effectiveness of competitive preservatives.

2. Field studies by means of test specimens or installations of timber in actual service to compare the effectiveness, reliability, permanence, and economy of various preservatives.

3. Laboratory and field studies on the control of molds and stains during the seasoning and storage of lumber and similar material, and the control of stains, storage rot, and insect attack during the storage of logs, poles, and the like.

4. Basic studies on the penetration of preservatives into wood and how it may be favorably influenced by the proper correlation of heat, pressure, vacuum, and time during the preliminary conditioning or the treating period.

5. Studies to develop cheaper and more convenient methods of injecting preservatives into wood, and to promote and encourage the wider use of wood preservatives.

6. Development of new glues having greater permanence under adverse conditions, and having greater reliability. Cheapness and convenience are also desired.

7. Investigations on the technique of gluing by hot-press and cold-press methods.

8. Studies on the permanence of paint on different kinds of wood and of methods of increasing the durability of paint on houses.

9. Studies on the formulation, classification, and grading of paints for use on wood, to make possible more specific and more correct instructions for the application and maintenance of paint coatings on wood.

10. Studies of the effectiveness of moisture-resistant or moisture-repelling films and treatments.

11. Studies on the prevention of swelling and shrinkage by impregnation with resin-forming materials.

12. Improvements in physical and mechanical properties by resin impregnation.

13. Development of methods for testing the fire resistance of wood and wood structures.

14. Investigations on the effectiveness of fireproofing wood by impregnation or coating with suitable materials.

15. Studies on the improvement of fire resistance through design and construction details and the use of mechanical barriers.

16. Investigation of materials and methods for increasing the resistance of wood to chemical attack.

SUGGESTED RESEARCH

Since the modification and improvement of wood properties offer such great opportunities for benefiting both the consumer and the producer and for increasing the utility of wood and the certainty of satisfaction from its proper use, the research work in this field may justifiably be greatly expanded. The following projects have been suggested, both for new work and for more vigorous attack on unfinished work.

1. Study the cutting and drying of veneer in order to produce higher quality veneer with less waste and to produce good veneer from lower grade logs or other species than are now considered acceptable.

2. Study development of better and cheaper preservatives to protect wood from decay, termites, and other destroyers.

3. Develop cheaper and more convenient methods of treating and prolonging the life of farm fence posts.

4. Make more thorough and comprehensive field tests and service record studies to compare the effectiveness of different preservatives.

5. Study methods of conditioning, handling, treating, and protecting northern hemlock and hardwood railway ties to improve the serviceability and marketability of these unpopular woods for ties.

6. Study the technique of gluing wood to wood and wood to metal, and develop improvements.

7. Study the classification and grading of paints so that more accurate and specific directions can be given with regard to their selection, application, and maintenance.

8. Study the painting of wood and the formulation and application of paints to increase their durability and effectiveness.

9. Study the finishing of wood floors to develop the most effective and economical materials and methods of finishing and maintenance.

10. Study the effectiveness of chemical impregnation for fire-proofing wood and develop more effective and less expensive formulas and methods.

11. Develop better coatings for improving the resistance of wood to rapid spread of fire and study the limits of their effectiveness.

12. Improve the design and construction of wood assemblies, building units, and buildings to make them more safe from fire.

13. Study the development, comparison, and grading of new glues, with special attention to the production of glues that are highly resistant to deterioration and that can be used without hot pressing.

14. Improve and lower the cost of the synthetic-resin method of shrinkage prevention and broaden its field of usefulness.

15. Study the possibilities and limitations of the water repellents frequently used for the treatment of millwork and develop better ones, if possible.

16. Study the special problems involved in the treatment of window sash and other millwork for prevention of decay and stain.

17. Develop improved materials and methods for preventing blue stain in lumber and logs during seasoning and storage and in lumber products in use.

18. Study improvement of materials and methods for preventing storage and seasoning rots in poles, piles, logs, ties, and similar products.

19. Study methods of preventing the bleeding of resins through paint films.

20. Study the painting of wood treated with preservatives.

21. Study the details of heating wood in various heating mediums for softening veneer logs, sterilizing lumber and structural timbers, improving preservative treatment, and similar processing, for the purpose of improving the results.

22. Improve the results obtained through pressure impregnation of wood by devising better ways to condition the timber or control the treating conditions and thus bringing about deeper and more uniform penetration.

23. Study the improvements in wood properties obtainable through combined resin impregnation, gluing, and compression. The very dense, heavy, hard, strong, water-resistant product thus produced promises to serve well for products requiring these properties.

24. Study finishes for furniture and interior trim to develop improved practices.

25. Study the details of house construction with a view to development of improved methods for avoiding decay and insect damage and of making effective repairs to damaged structures.

TIMBER PHYSICS

Timber physics is a broad term applied to fundamental research on the physical properties of wood; applied research on all wood-moisture relationships (largely the seasoning of wood); and special lines of research such as construction problems involving moisture effects.

Some of the more important economic considerations of this research are:

1. Broadly, the results of seasoning research are applicable to most of the 15 to 20 billion board feet of lumber and other sawed products and to a goodly portion of the other wood products annually cut in our forests and woodlots.

2. Current losses in the seasoning of lumber and timber due to seasoning degrade alone run into many millions of dollars, and better drying practice should be able to salvage well over \$10,000,000 per year.

3. The economic utilization of weed species, representing billions of feet of standing timber, will depend in large measure upon the development and application of improved seasoning methods.

4. Broadly, all seasoning research has application in the construction industry, which consumes 60 percent of the country's entire lumber cut. Specifically, the results of the researches on condensation of moisture in walls, attics, etc., apply in large measure directly to all residences, both new and old. Indirectly, and through further study, they will apply to other occupancies, particularly to dairy barns in the colder climates, which suffer severely from winter condensation.

PRESENT RESEARCH

The following research projects are in progress:

Construction.

1. Studies of moisture movement and condensation: Comparatively recent improvements in house design and construction have served to increase and accentuate condensation troubles arising from high indoor humidities during cold weather. Progress has been made in the study of the causes underlying the condensation of moisture in walls, ceilings, and attic spaces, and in the development of remedies for the difficulty. The effectiveness of many vapor barriers of various kinds has been measured, and the characteristics of many types of wall construction determined. Studies on the effectiveness of the ventilation of walls as a means of keeping them dry are under way.

2. Intensive fundamental studies on the heat conductivity of wood and of wood impregnation.

3. Studies of heat and water-vapor loss from a prefabricated stressed-covering plywood house to show the effectiveness of insulated plywood walls with moisture barriers for modern house construction.

Chemical seasoning.

4. Customary methods of air seasoning and kiln drying are effective for many items of lumber and other wood products but do not permit the satisfactory seasoning—free from defects—of certain refractory species or of the larger structural sizes of all species. To provide a way to do this difficult seasoning effectively, considerable research has been devoted to chemical seasoning methods in which the wood is treated with water solutions of various chemicals before the conventional drying methods are applied.

Kiln drying.

5. Kiln schedules: The artificial drying or seasoning of lumber in kilns is one of the two common methods of removing moisture from green wood. To carry out this method effectively it is necessary to

have a suitable formula or recipe for each species and item to be dried. This recipe, customarily called a kiln schedule, usually specifies the temperature and relative humidity of the drying atmosphere to which the material is to be exposed at the different stages of the drying process. Broadly, also, it may indicate the degree of control or quality of the dry kiln itself.

Research in kiln drying, for many years, has involved the development of drying schedules for the commercial species of the United States. Associated with this has been a study of the fundamentals of wood drying and the perfection of several types of lumber dry kilns. At present, effort is being concentrated on the revision of schedules which were set up a number of years ago when kilns were not so efficient as at present, and on a study of the fundamental relationships between rate of air circulation in the dry kiln and the speed and quality of the drying.

SUGGESTED RESEARCH

In addition to current lines of research, which must be continued and which could well be expanded, are the following urgent and important fields which need attention:

1. Moisture content in use: Preliminary information on the moisture content of wood in nonair-conditioned dwellings is available now, but very little information is available on air-conditioned occupancies and on the many other uses of wood. Much more is needed before it will be possible to write suitable "moisture specifications" for the many uses of wood and to furnish the forest-products industries satisfactory answers to the important question, "How dry should wood be for this use?"

2. Physical properties of plywood: The use of plywood (sheets of veneer glued together into boards of various thicknesses) has increased tremendously in the last few years, and the demand for information about its properties has increased correspondingly. Needed immediately is extensive information on the amount of shrinkage and swelling which takes place with moisture changes in the board and how this movement may be reduced by variations in the construction of the plywood.

The best methods of drying veneer and the plywood boards made from it need to be developed; present methods are wasteful of time and material.

3. New wood-drying or seasoning methods: Chemical seasoning is but a partial answer to the demand and need for improved seasoning methods, and even better methods are required. Increased knowledge of wood and important developments in various sciences have opened up some new avenues of approach which should be explored. One of these is the use of short-wave electricity as is done in modern "fever machines." Another is the development and application of anti-shrink methods.

4. Second growth: It is recognized that the properties of young second-growth timber may vary considerably from those of mature virgin stands. Shrinkage and warping tendencies are doubtless greater, due in part to larger proportions of sapwood, more knots, and greater percentage of growing stresses not yet relieved by time and age. To a certain degree it will be necessary, as more and more second-growth material is cut and marketed, to repeat on this class of

stock research already done on mature timber. Especially should this be done on shrinkage and on kiln-drying schedules.

5. Fundamental research: Knowledge of the fundamental physical properties of wood is incomplete. The properties not mentioned elsewhere which need study are: Sound insulation (acoustical properties); sound amplification (sonics); electrical properties of wood; and effect of temperature on physical properties of wood.

RELATION OF GROWTH, STRUCTURE, AND PROPERTIES

Almost two-thirds of the forest area of the United States is covered with second-growth timber, which in general is inferior to virgin growth. The trees are smaller, more knotty, contain a higher percentage of sapwood, and if used for wood yield products which are generally of low grade. Their use as a source of wood pulp, however, is standard practice in many parts of the country.

Under current utilization practices there is a very limited market for second-growth wood in competition with quality products from virgin timber and industrial substitutes from other materials.

The difficulty of marketing this low-grade material not only represents an economic loss of a potentially valuable resource but seriously interferes with the proper silvicultural management of forests by preventing the economic removal of thinnings. The situation is discouraging to productive forestry by farm and commercial forest landowners and a serious obstacle to the economic rehabilitation of submarginal agricultural lands.

The problems enumerated under this caption are concerned with research looking to the relationship between the various conditions of growth and the properties of the wood produced, and the relationship of wood structure and wood properties.

PRESENT RESEARCH

The following lines of research are in progress:

1. Research with the purpose of producing the maximum volume growth of wood per acre.

2. Considerable work in producing rapidly growing strains, races, and hybrids of forest trees.

3. Study of the relationship between the rate of growth and workability, paintability, and ability of wood to stay in place is under way.

4. Research on the following cultural factors: (a) The effect of soil moisture, especially during the summer season, on the percentage of summerwood, and hence on the strength, of pines; (b) the effect of flooding (as in the Mississippi Delta) on the density and strength of wood and its effect on swell-butting of certain species; (c) the effect of leaning coniferous trees on type of wood produced on the lower side of the stem; (d) the effect of pruning of limbs of certain species of pine on percentage of clear lumber or lumber free from loose knots; (e) the effect of size of crown on the percentage of springwood, and hence on the density of the wood, of southern pines.

5. The characteristics of heartwood as compared with sapwood, and factors influencing heartwood formation.

6. The relation of the cellular structure of wood to its properties.

7. Studies of the physiology and biochemistry of oleoresin formation.

8. Classification of structure and other characteristics of native and exotic species to facilitate their identification.

SUGGESTED RESEARCH

The following lines of work have been suggested:

1. A more extensive and intensive study to determine the variations in properties between second growth and virgin growth and the causes of those variations. The study should relate both to use as wood and to value for pulping.

2. Study of the effect of environmental growth conditions of trees on the structure, chemical composition, and properties of the wood formed in them, as a basis for determining the proper silvicultural management for growing timber of specific quality.

3. Study of the relation of cell structure of wood to its properties, in order to give a broader understanding of variations in wood properties as between species or between individual trees of the same species. The study offers possibilities of explaining the manner in which moisture moves through wood, of explaining variations in strength and other properties of wood, and of accurately diagnosing the results of tests. The project is of fundamental character, and little progress has been made to date.

4. Determine the practicality of pruning both softwoods and hardwoods and the best methods for so doing for the purpose of improving the quality of second growth, particularly of hardwoods, upon which no work has yet been done.

5. Develop trees with highly valuable figured wood, and those combining rapid growth and high quality.

6. Continue the classification of wood characteristics of native and exotic species to facilitate their identification.

7. Conduct fundamental studies in the physiology and biochemistry of the formation of wood, bark, and leaves, including extractable materials of forest trees, shrubs, and herbs so that forest growth may be better understood and managed and further research in the utilization of forest products more intelligently directed.

8. Extension to hardwoods of studies on type of wood produced on the lower side of the stems of leaning trees.

MECHANICAL CONVERSION METHODS

For a considerable time to come the more familiar uses of wood, such as lumber, plywood, ties, poles, posts, and fuel, will continue to absorb a relatively high percentage of the total production from farm woodlands and commercial holdings. The status of wood in these forms is gradually being improved by application of the better practices already worked out in processing and utilizing the products. Still greater improvements lie ahead as the contributions of research are brought fully to bear on certain characteristic problems of the forest industries that center around heavy wastes in logging and milling, low-grade and little-used species which are unsuited to present utilization methods and which hamper intensive forest management, inadequate and unorganized standards for quality segregation and marketing, and in general a backwardness in mechanization of handling and processing methods to keep the forest industries abreast with other more modern industries.

In a manner peculiar to forest industries, harvesting as well as conversion methods have an important bearing on the utilization of surpluses and low-grade material. Immature timber, that is, timber too small to pay its way, all costs considered, is being harvested in large quantities, especially from the farm woodland. Low-grade products and inadequate returns result from misconceptions as to what is merchantable timber. Important betterments all along the line depend upon changes in forest management and cutting practices which involve harvesting only those sizes that are capable of returning a profit and leaving the smaller sizes to grow until better than low grades are procurable.

PRESENT RESEARCH

1. Timberland owners, large and small, have been provided during the last decade with the results of much systematic research in practically all regions of the country on logging and milling costs and returns as they relate to selective logging in lieu of clear cutting. Handbook data on timber quality in terms of lumber-grade yields by log and tree sizes for the important hardwood and softwood species have been prepared and given wide distribution. To arrive at these values some 50 logging and milling operations in all forest regions have been intensively studied by production steps from the stump to the lumber pile.

2. A principle of grading sawlogs of hardwood species is under development that results in elimination of the undesirable overlapping in values in different log classes that have characterized attempts at log grading heretofore. Previously no adequate basis of fact has existed as to exact relationships between external characteristics of different kinds of logs and their effect on the grade of lumber procurable from them. Standard log grades which both mill buyers and sellers, particularly farmers, can use advantageously have never been developed or recognized outside of limited commercial log markets in the Pacific Northwest. They are urgently needed in the farm forestry regions of the South and East. For pulpwood a grading system is in evolution whereby the variables of growth, density, and knottiness are taken into account in the ways that pulp and paper research finds to be important in diversified production.

3. The utilization of second-growth timber, greatly accelerated by the recent introduction of truck logging, has brought into special prominence the small sawmill, particularly of the portable type. As a means of avoiding the serious drawbacks of the present circular sawmill a new type of portable band mill is under development. It introduces radical changes in layout and operation which, if ultimately successful, will increase portability and economy in sawing by substantial proportions.

4. Research over a period of years has developed the commercial feasibility of cutting low-grade and defective hardwoods into dimension stock rather than lumber, that is, cutting logs or bolts at the source of supply to the exact sizes or multiples of the parts used in fabricated products, such as furniture. Important commercial developments have arisen from research on form of product, costs, methods, and standards of manufacture, seasoning, grading, and packaging.

5. Utilization measures adapted to cooperative farm woodland management are receiving substantial attention by research agencies to devise methods of manufacture and products suited to moderately

small-scale but efficient operation, decentralization of manufacture and employment, and so far as possible serving local markets. One broad aim is to provide the modern counterpart of the local planing mill that used to exist and which in equivalent needs to be revived, if possible, in the interests of farm forestry.

6. The development of national standards for lumber grades, nomenclature, thickness, and moisture content in conformance with consumer needs has made substantial headway, to guard against the evils of skimpy lumber sizes and jerry construction in the housing and farm-building fields.

7. The machining qualities, especially planing, turning, and shaping characteristics, of little-used hardwood species are being established through recent research to make it possible for the wood-fabricating industries to use the weed as well as the favored species.

SUGGESTED RESEARCH

The following lines of research are suggested:

1. Extension of previous work on log grades to include the many species not yet covered.

2. Mechanization in the collection, preparation, and handling of small and defective logs and bolts to reduce costs and thus permit utilization in the form of pulpwood, chemical wood, and firewood of much material now wasted in the woods.

3. The testing of improved wood stoves and furnaces as recently developed in Europe and modifications in design required to meet domestic demands, especially for central heating systems. Special attention needs to be given to more economical and convenient forms of fuelwood for use with automatic or semiautomatic feed.

4. Continuation of work on machining qualities of lesser used and refractory species, especially hardwoods, to develop optimum cutting speeds, knife angles, etc., to compensate for inherent characteristics of each species.

5. Development of portable band mill for economical conversion of scattered and small blocks of timber and similar measures adapted to cooperative management and processing of farm woodland timber.

NAVAL STORES (TURPENTINE AND ROSIN)

The principal products now classed as naval stores, which originally meant pine tar and pitch, are gum spirits of turpentine, gum rosin, steam-distilled wood turpentine, wood rosin, destructively distilled wood turpentine, and sulfate wood turpentine. For these turpentines and rosins standards have been set up under the Federal Naval Stores Act. In addition to these, there are certain derived products, such as "sulfate wood rosin," pine tars, pine oils, pitches, tar oils, rosin spirits, and rosin oils. The term "gum naval stores" refers specifically to gum rosin and gum spirits of turpentine, whereas the remaining turpentines and rosins are referred to collectively as "wood naval stores."

Gum naval stores, derived from the oleoresin of living southern yellow pines, are by far the more important group with regard to value, number of persons employed, area involved in production, and economic utilization of the land. Approximately 30,000,000 acres of

pineland out of the nearly 50,000,000 acres in the Naval Stores Belt produce the annual crop of gum turpentine and rosin. The Naval Stores Belt includes North Carolina, South Carolina, Georgia, Florida, Mississippi, Alabama, Louisiana, and eastern Texas. About 350,000 people are dependent almost entirely upon the income from the production of the crude gum or its derived products, turpentine and rosin. The annual production varies widely, ranging from 750,000 barrels of gum turpentine and its accompanying rosin in the 1908-9 season to 340,000 barrels in 1918-19. The average is about 500,000 barrels. The production of gum naval stores for the 1937-38 season was about 520,000 units (a unit is one 50-gallon barrel of turpentine and three and one-third 500-pound barrels of rosin). The average annual value of the crop to producers is approximately \$25,000,000. The price of turpentine has ranged from more than \$1.50 per gallon in 1922 to 20 cents per gallon in 1938. Rosin prices have fluctuated as widely. These wide fluctuations in prices are due to fluctuations in volume of production, in carry-over, and in demand.

Normally 55 percent of this country's production of naval stores of all classes is exported. The percentage and quantities exported have decreased in recent years, owing primarily to the efforts of some important foreign consuming countries to be self-sufficient in these raw materials. A change in source of supply by those countries unable to produce naval stores has also tended to reduce exports from this country.

A recent timber survey by the United States Forest Service indicates that virgin and second-growth southern yellow pines are capable of yielding annually 800,000 units of gum naval stores (on a sustained-yield basis) and 300,000 units of wood naval stores, a production far in excess of any in the past.

Finally, because of low market prices for staple agricultural crops of the South, efforts are being made to establish a balance between supply of and demand for these crops by an adjustment of land use. The increasing production of pulp from southern pines is a step in this direction. A combination of the pulp and naval stores industries promises to create a reforestation movement in the South which will permit an economic use of the vast acreage of cut-over timberland and marginal farm lands.

All of these factors lead to the conclusion that the production of gum naval stores, although not very profitable at present because of low prices and high costs, will increase rather than decrease.

The answer to the problem lies in improved forest management which should result in reduced unit cost of production, more economic methods of processing and marketing, and finally, but of greatest importance, the development through research of new products and new markets.

The producers of wood naval stores are actively engaged in scientific research for improving their processes and products and developing new products and uses. Most of the research on gum naval stores, which have been classed as agricultural commodities by the various producing States and by the Federal Government, is carried on by the Federal Government.

PRESENT RESEARCH

Present research may be classified as follows:

1. Studies on forest management of the naval stores pines.
2. Research on gum (oleoresin) production including—
 - (a) Basic investigations of gum production along anatomical and physiological lines.
 - (b) Gum-extraction methods, particularly with respect to height and depth of chipping, type of face, cup-and-gutter installations, etc.
 - (c) Gum-yield studies according to different tree size, tree-growth characteristics, and forest site quality.
 - (d) Gum-flow studies, concerned with influence on rate and amount of gum yield of such factors as weather and fire.
3. Investigation of methods of production, processes, and equipment, including—
 - (a) Development of steam turpentine still.
 - (b) Development of gum cleaning processes and equipment.
 - (c) Design and operation of turpentine fire still plants.
 - (d) Studies on turpentine cups to determine the effects of the various materials of which cups are made on the oleoresin and its products.
 - (e) Conditioning of turpentine to prevent deterioration in storage.
 - (f) Improvement of shipping containers.

Fundamental research.

4. General investigation of the composition and properties of oleoresin, rosins, turpentine, and other naval-stores products and the properties of their components and derivatives.
5. Studies on hydrogenation and oxidation products of pinene.
6. Investigation of products that might be obtained from rosin by cracking.
7. Research on physical and chemical conversion of oleoresin to new products.

Utilization.

8. Experiments on the use of turpentine and of its components and derivatives.
9. Studies of the significance and origin of color in rosins.
10. Experiments on the use of rosin for lining for brewing vats.
11. Experiments on the use of rosin soaps in pine-oil disinfectant emulsions.
12. Experiments on the utilization of modified rosin acids.
13. Experiments on the direct use of oleoresin.
14. Experiments on the utilization of byproducts of the sulfate-pulp industry.
15. Experiments on the utilization of minor constituents of naval stores products.

SUGGESTED RESEARCH

The following suggestions have been submitted by industrial and research organizations interested in naval-stores problems:

1. An economic survey of the naval-stores industry with the following objectives:
 - (a) To show present and potential pine timber supply by keeping up to date the timber survey of the United States Forest Service.
 - (b) To make possible a study of the factors affecting gum farming.
 - (c) To determine the soundness of the present system of quoting and marketing turpentine and rosin.

(d) To study potential markets for turpentine and rosin as such.

(e) To study the financial returns from management and utilization of the forests for gum naval stores singly and in combination with various other purposes—pulpwood, timber, etc.—with the object of attaining maximum permanent economic and social benefits.

2. Forest genetics investigations with naval stores pines aimed at segregation of high-yielding strains and development of new varieties of superior gum-yielding capacity.

3. Expanded forest-management investigations to develop practicable and sound silvicultural methods of producing timber for gum naval stores as the primary crop and for gum naval stores in combination with good yields of pulpwood, lumber, poles, and other wood products.

4. Development of special gum exploitation methods aimed at short-period heavy yields from trees marked for removal in pulpwood thinnings or other wood-harvesting cuttings.

5. Increased investigations to determine the possibility of developing products of industrial value, other than turpentine and rosin, direct from the oleoresin.

6. Development of efficient methods of purifying the oleoresin to permit further processing and storage.

7. Greatly expanded studies on the chemistry of naval stores, including:

(a) Composition of the pine oleoresin, and the factors affecting the composition of oleoresin and products directly derivable from it.

(b) Composition of the various turpentines and pine oils, with special emphasis on less-known constituents, and the possibility of converting turpentine constituents into chemicals higher priced than turpentine.

(c) Extending the number of possible derivatives from the terpene portion of turpentine.

(d) Production of stabilized resin and rosin acids.

(e) Composition and factors affecting composition of the destructive distillation products of pine wood and rosin.

8. Study of naval stores as possible sources of sterols and plant hormones.

9. Utilization of modified resin and rosin acids in industrial products, such as soaps, paper size, ester gums, synthetic resins, and plastics.

10. The conversion of turpentine into organic solvents or driers other than those now available.

11. Combination of turpentine with fatty acids for the production of products useful in industry.

VEGETABLE TANNING MATERIALS

The vegetable tannins are important and essential materials for the production of leather and leather goods. Normally 15 to 20 million dollars' worth of tanning materials are used each year in this country for making leather. These are derived from the bark, wood, leaves, fruits, and roots of plants. This annual consumption, in terms of 25-percent tannin extract, is equivalent to about 450,000 tons. The tannins are used to make vegetable-tanned leathers, especially the heavy leathers, such as sole, belting, harness, case, bag, and strap, the average annual production of which in this country is estimated at about 425 million pounds.

One-half of the tannins for making this leather come from foreign countries. Displacement of these foreign materials by domestic ones offers a potential increase in home production of approximately 10 million dollars annually.

Our most important domestic source of tannin is the wood of the American chestnut tree. Chestnut wood, together with quebracho wood of South America, now furnishes two-thirds of our total supply of tannin for making leather. The chestnut, as is well known, is being steadily and rapidly exterminated by the chestnut blight.

While there may be no immediate cause for alarm over severe shortages in our supply of tanning materials, inroads by man and disease are steadily making for exhaustion of our recognized domestic sources. A forward-looking program for national welfare, through maintenance of a safe measure of economic and industrial independence in the production of leather, demands the development of new home supplies of tanning materials. A most promising approach to the solution of this problem would appear to lie in the cultivation of highly tanniferous plants harvested annually, or at least every few years. Such a program, in addition to supplying needed raw materials for industry, would offer opportunities to provide new crops and hence new sources of income for agriculture, and to diversify the use of land, thus reducing acreage now producing surplus crops.

PRESENT RESEARCH

Research work directed toward the conservation of domestic tanning raw materials, the development of latent sources, and the creation of new home supplies is extremely meager. A recently completed Federal survey on the possibility of economically converting waste hemlock bark of the Pacific Coast States into tanning extracts has paved the way for commercial development. Research projects now in progress are as follows:

Development of tanning materials.

1. Studies of the chestnut blight and attempts to introduce and establish in this country Asiatic blight-resistant chestnut trees.

2. Cooperative Federal and State research on a very limited scale upon the development of new domestic tanning materials, preferably as new farm crops. Attention is being centered at present on canaigre and sumac.

3. Studies on the adaptability of various plants and trees, including tannin-bearing plants, to hillside culture for prevention of soil erosion.

4. Research in the leather and allied service industries on further development of improved and new synthetic tanning materials of the general class comprising condensation products of aldehydes and phenols. Thus far these have displaced vegetable tanning materials to only a minor degree. Particularly is this true in the tanning of heavy leathers.

5. Active research directed toward the recovery and modification of waste sulfite cellulose liquors from the production of wood pulp, to obtain products capable of greater application in the tanyard or in the actual tanning of hides and skins.

Utilization of tanning materials.

6. Studies by chemists in the leather and allied industries of the properties of the various vegetable tanning materials to promote the more scientific blending of the agents in tanning formulas and their most efficient and economical utilization in producing leather.

7. Research on the chemical constitution, structure, and synthesis of the natural tannins, on the optimum conditions for the extraction and leaching of tanning raw materials, and on the clarification, sulfiting, decolorizing, and blending of tanning extracts.

8. Some studies of uses for tannin, other than in making leather, new products that might be derived from the tannins, and utilization of spent tanning raw materials.

SUGGESTED RESEARCH

Research suggested in the more important fields of work on vegetable tanning materials is as follows:

1. The early development of new domestic supplies of tanning materials, primarily for making leather, with specific recommendations that consideration be given to the sumacs, wattles, mangroves, fruit and pod tannins, and gambier or its equivalent.

2. Study of the tannin content of the flora of the world, particularly of Central and South America, with the object of discovering plants that might be developed in this country as new sources of tannin.

3. Determination of the optimum conditions for the commercial extraction of tanning raw materials and the preparation of tanning extracts.

4. Determination of the constitution and properties of the natural tannins to secure fundamental data on the blending of materials and more scientific methods of assaying tannin in plants, extracts, and tan liquors.

5. Study of the use of the tannins in the production of plastics.

6. Study of the most complete and profitable utilization of spent tanning raw materials.

SPECIALTY CROPS

DRUG AND OTHER SPECIAL PLANTS

This group includes a variety of plants furnishing products for a number of industries. Only a few are grown commercially in the United States, but many of the others have from time to time been considered with regard to their possibilities as domestic crops. For convenience the most important ones in the group are listed herewith on the basis of the class of products obtained from them. Other plants usually included in the group are not listed here because they are discussed elsewhere. Among these are plants yielding vegetable oils, such as tung, soya, linseed, safflower, perilla, and chia; castor beans; canaigre and sumac as sources of tannin; tobacco waste and special species and types of tobacco for nicotine as an insecticide; and hops for brewing.

Drugs: Digitalis, belladonna, henbane, stramonium, cascara, golden-seal, ginseng, Levant wormseed, licorice, ephedra, poppy, psyllium, and many others.

Essential oils: Peppermint, spearmint, Japanese mint, wormseed, wormwood, dill lemongrass, citronella grass, vetivert, rose, geranium, lavender, coriander, caraway, fennel, basil, and others.

Condiments and spices: Mustard, red pepper, sage, thyme, and other savory herbs.

Insecticides: Pyrethrum, derris, cube, timbo, and devil's shoestring.

The foregoing list could be greatly extended but is restricted here mainly to those plants that have had most attention, that have been most frequently suggested as worthy of study, and that are important, although not in all cases vital, sources of materials for the industries.

Inasmuch as the plants in this group are relatively not well known and information regarding them is widely scattered in the literature, brief mention is made of some researches of the past, particularly of the types that are most frequently suggested for future work.

DRUGS

On the whole, research in this group of plants has largely concerned itself with adaptation studies, cultural requirements, crop possibilities, determination of yields, examination of products obtained, and phases closely related to these. Much research has been done by Government and State institutions and colleges of pharmacy, but in some cases the large consumers have made investigations of and grown such plants in endeavoring to establish a local and dependable supply of raw materials. This is especially true of the botanical drugs. Digitalis, belladonna, henbane, stramonium, and numerous minor ones have been studied in numerous localities, and their cultural requirements are quite definitely known. Ginseng, goldenseal, and Levant wormseed are established commercially, and their growers are well informed by experience and preliminary investigations. During the World War when prices were high, this type of research was stimulated by the fact that many of the botanicals could not be obtained from Europe. Much was learned about their cultivation during those few years.

While the most direct interest was in yields and returns, attention was also given to related phases, particularly the quality of the drugs obtained and the relation of various factors to strength and other qualities. It was realized that domestic culture of such plants must be on a competitive basis, and it was sought to offset higher production costs with greater market value resulting from superior quality. As an example, there were selection studies with belladonna, whereby its alkaloid content was increased two and threefold.

An important agency in promoting studies on medicinal plant culture in the last two decades has been the medicinal plant gardens maintained by colleges of pharmacy. Although primarily intended as aids in teaching, they serve also as a means of determining the adaptation of species, because these gardens are widely distributed.

Through the collaboration of the National Research Council a beginning has been made in a survey of the distribution and supply of native medicinal plants as a basis for determining future supplies. In the Pacific Northwest the expected serious decline in the world's supply of cascara bark led to researches on the propagation of the native cascara tree and on less destructive methods of collecting the bark.

In recent years investigations were begun, mainly in the Southwest and in South Dakota, of the possibility of growing several species of *Ephedra* to insure a domestic source of the important alkaloid ephedrine. Subsequently the armed conflict in China, which is the principal source of the drug, has cut off the supply, thus emphasizing the value of that type of research.

The production of natural camphor from cultivated camphor trees in Florida was the subject of intensive research which led two large corporations to plant large acreages. Excessive costs of production and the commercial development of synthetic camphor were responsible for the failure of these enterprises.

The possibilities of growing tea in the South have been thoroughly explored, and much information on the subject has been obtained in connection with an unsuccessful commercial attempt to grow this crop in South Carolina.

Psyllium seed production was investigated in Illinois, and licorice culture was tried in Louisiana and California.

ESSENTIAL OILS

The essential oil crops of the country in the order of their importance are peppermint, spearmint, American wormseed, and wormwood. The first two, comprising the mint industry, provided a cash income in 1937 of 1,760,000 dollars. Much has been published on mint culture and on these two mint oils. While the industry has its problems, these are not primarily associated with lack of quality in the oils but rather with maladjustment of supply and demand. A serious disease of mint in Michigan, which threatens the industry, is being investigated to find practical methods of control.

The oil from the Japanese species of mint, grown only in Japan, is the source of natural menthol, of which it contains about 80 percent, as compared with 50 percent in the oil of American peppermint. An exhaustive investigation has been made of the possibilities of this species as a domestic crop. It was found adapted to many sections, and the relation of numerous factors to menthol content were determined. Present low market value of menthol and production of synthetic menthol forced abandonment of the crop in California.

In central Maryland the wormseed-oil industry has been studied particularly with respect to the effects of methods of distillation on the ascaridole content of the oil. Other researches on this crop have been made in Illinois and South Dakota. In the latter State the use of wormseed as forage with incidental anthelmintic effect was investigated.

The aromatic grasses, vetivert and lemongrass, were studied in Florida, and recently the latter has been the subject of special research in the Everglade section.

The utilization of roses as a source of attar of rose in Oregon and California has been investigated. Rose geranium oil, widely used in perfumes and soaps, was grown experimentally in Florida, Texas, and California, and the excellent quality of the oil produced was demonstrated. Likewise, in the Pacific Northwest similar work is being done with lavender. Basil was shown to be a promising oil crop, requiring only a larger market outlet.

INSECTICIDES

The rotenone-containing plants now used require tropical conditions for growth and are not adapted to the continental United States except southern Florida, where adaptation studies of several species of derris are under way. It is possible that their culture could be established in some of our insular possessions. Six native plants belonging to the genus *Tephrosia* are known to contain insecticidal principles such as rotenone or deguelin. One of these, the devil's shoestring (*Tephrosia virginiana*) of the South and Southeast, contains these ingredients in sufficient quantities to suggest its commercial use.

PRESENT RESEARCH

The following research is now in progress:

1. Studies of the antiseptic properties of *Agarita*, a native of west Texas.
2. Researches on aloe culture in Florida as a result of the recent use of aloes in the treatment of X-ray burns.
3. Researches to reestablish medicinal plant culture on small farms in New England with family labor. Special attention is being given to marketing problems.
4. Study of the hemp plant and its products in relation to the marihuana problem.
5. Studies of the properties of wormseed oils from plants obtained by cross-fertilization.
6. The production of dill oil as a substitute for dill herb in pickling.
7. Researches in production of coriander oil.
8. Studies of the possibilities of fennel herb oil.
9. Improvement in the yield and quality of red peppers.
10. Cultural studies of savory herbs.
11. Extensive researches of the crop possibilities of pyrethrum as an insecticide. These include cultural studies and investigations of toxicity of the flowers under various conditions, improvement of yield and quality by selection, and design of harvesting equipment to reduce cost of production.
12. Investigations on the devil's shoestring (*Tephrosia virginiana*) to determine its rotenone content and crop possibilities on poor, sandy soils. More toxic strains are being located and developed.
13. Determination of the insecticidal properties and constituents of hellebore and *Physalis mollis*.

SUGGESTED RESEARCH

The lines of research that have been suggested in this field cover a wide range. For convenience they are divided into the same four groups as in the discussion. In some cases the research suggested has already been done or is under way entirely or in part. Other suggestions are merely what industry would like to have done, rather than definite research proposals.

Drugs.

1. The possibilities of drug-plant farming, particularly on small farms, to provide domestic sources of crude drugs and to make an outlet for unskilled labor should be explored. This investigation may in some cases be in collaboration with erosion control studies.

2. The survey of native medicinal plants should be extended and means of improving their collection to provide better material for the drug industry studied.

3. The study of stramonium as a source of atropine and other alkaloids to improve alkaloid yield should be undertaken.

4. A domestic tea industry, especially as a source of caffeine, might be developed.

5. The active principles of drug plants should be synthesized.

6. Domestic sources of opiates might be developed.

7. Study of means of modifying alkaloids to reduce their toxicity is suggested.

8. The constituents of drug plants should be investigated.

9. The possibilities of lac production in the Southwest need investigating.

10. The possibilities of acacia and tragacanth-gum production in the Southwest should be examined.

11. New possibilities of assuring supplies of quinine, including the feasibility of extracting seedlings, should be explored.

12. The commercial growing of *Ephedra* to insure a source of the alkaloid ephedrine has possibilities.

13. Sources of plant hormones should be investigated.

14. Study of adsorption methods for concentrating active constituents of plants is desirable.

15. Study of the composition of botanical drugs from the standpoint of their use in flavoring liqueurs and determination of their cultural requirements are worthy of investigation.

16. The cost of growing medicinal plants is generally high, due, in many cases, to excessive harvesting costs. A general study of this question with a view to designing mechanical harvesting devices for the plants otherwise most promising is recommended.

Essential oils.

17. The possibilities of domestic production of essential oil plants should be investigated, and researches on the composition and quality of the oils in comparison with foreign oils should be conducted. These studies should include the variation in such oils due to differences in strains within the species.

18. A comprehensive investigation should be made of the essential oils from native and introduced plants, and their usefulness in the industries to secure a greater measure of independence from foreign sources of supply should be determined.

19. The use of ultraviolet adsorption curves as a means of identifying oils should be studied.

20. The art of refining and blending essential oils for perfumery requires thorough study.

21. The possibility of growing citronella grass in Florida should be thoroughly explored. Citronella oil is the most economical raw material for the synthesis of menthol.

22. The development of new uses for geraniol, a byproduct from citronella oil in the synthesis of menthol, should be studied.

23. New uses might be found for lemongrass oil to promote the success of its culture in the Everglade section of Florida.

24. Attempts have been made to grow vetiver, the roots of which are the source of a valuable oil used as a fixative in perfumes. The

method of distilling this oil, and various aspects of the plant's culture in the South, require thorough study.

25. Researches are needed on the utilization of surplus and otherwise unmarketable flowers, such as roses, narcissus, and gardenias, from nurseries, bulb farms, florists' shops, and other sources for the production of perfume oils.

26. The possibility of diverting peppermint oil of poor quality from regular market outlets for the production of menthol might be investigated. This investigation would stabilize the price of good-quality oil.

27. The rate and degree of deterioration may be determined of the essential oils of aromatic oil seeds, such as coriander, caraway, anise, and fennel, under various conditions of storage.

28. The comparative value of dill herb and dill oil for flavoring purposes, particularly in pickles, should be studied.

29. Researches are suggested on new uses for essential oils in flavoring beverages, liqueurs, etc., and the possibility of utilizing oils from native species for which there is no market at present might be investigated.

30. A thorough study should be made of the repellent and insecticidal properties of essential oils with special reference to the control of clothes moths and other household insects.

31. A comprehensive survey is suggested of the present commercial production of oils from wild native plants, including studies of the methods of distillation employed, sources of material, probable future status, marketing problems, etc. This would include the conifer oils, wintergreen, sassafras, pennyroyal, sweet birch, and tansy.

32. Oils obtained as byproducts in other industries, or that can be so obtained, require thorough study to determine their possible usefulness or to extend their present market outlets. Examples of such are the oils from cedarwood, fruit kernels, and hops.

33. Producers of wormseed oil have long had a serious problem in the manipulation of their stills. The ascaridole content of this oil, on which its anthelmintic value is based, is greatly affected by steam pressure, temperature of condenser water, and other factors. A thorough technological study of this question will benefit growers and assure a less variable product.

Condiments and spices.

34. The effects of soil and climatic factors on the quality of mustard seed might be investigated. It is claimed that some of the seed produced in the United States is lacking in the bright yellow color and strong pungency of the English seed of the same variety.

35. The effects of soil, climate, and cultural practices on the flavoring qualities of species and varieties of savory seeds and herbs, such as anise, basil, caraway, celery seed, coriander, dill, fennel, sweet marjoram, summer savory, tarragon, and thyme, should be studied.

36. The superior quality of American-grown sage has always been recognized by the meat-packing and spice industries. The cost of harvesting has been the most serious obstacle to domestic sage growing. A thorough investigation of its possibilities from all standpoints, including methods of mechanical harvesting, adaptiveness to small farm units, value in erosion-control practices, etc., is suggested.

Insecticides.

37. There should be a continuous search for plants, preferably native or adapted to the continental United States, that have insecticidal value, are nontoxic to man and animal, and can be economically grown or collected.

38. Specialized research is needed on the role of rotenone in plant metabolism. It is necessary to know what factors determine or modify its production in the species of legumes in which it occurs. The success of the native devil's shoestring (*Tephrosia virginiana*) as a rotenone-containing insecticide plant on the sandy soils in the South will largely depend on such information.

39. A thorough study should be made of the susceptibility of the pyrethrum plant to various diseases, and an attempt made to develop resistant or immune strains that can be grown in the Cotton Belt in the South, and under irrigation in the Southwest, to which regions this plant is otherwise reasonably well adapted.

Hops

Hops are produced commercially in the United States principally in Oregon, California, and Washington, and to a small extent in New York. In 1937, 34,000 acres were devoted to the cultivation of hops; the output being 44 million pounds. This figure, however, does not include 4½ million pounds left unharvested on account of labor shortage and market conditions. In most seasons, farmers have received about 12 to 20 cents per pound of hops.

The only important use of hops is in the brewing of malt beverages, in which their flavoring and preservative qualities are of particular value. Hops grown in the United States are of high quality, although individual brewers sometimes prefer special varieties grown in foreign countries. It is desirable, therefore, definitely to evaluate or standardize the peculiar properties of hops which make their use desirable in brewing and thereby establish a basis for the improvement of the domestic product.

PRESENT RESEARCH

Active research is being conducted with a view to the improvement of domestic hops, including the following:

Agricultural research.

1. Improvement by selection and breeding.
2. Introduction of foreign varieties.
3. Studies on cultural methods and application of fertilizers for the improvement of hops for brewing.
4. Disease control, especially downy mildew.

Curing and processing.

5. Investigations on methods of drying and curing, sulfuring, baling, and storage, which directly affect the brewing properties of hops.

6. Studies of changes during ripening to determine the important brewing constituents which develop as the crop matures and indicate the proper picking time.

Fundamental research.

7. Studies relating to simple, accurate, and effective methods for the physical and chemical evaluation of quality.

SUGGESTED RESEARCH

Suggestions for further research on hops were as follows:

Agricultural research.

1. Further field work should be undertaken to aid in the reestablishment of the domestic hop industry on a broad permanent basis.

2. Domestic hops should be developed or improved to enable them to compete with or supplant imported products preferred by some brewers because of certain qualities not possessed by domestic hops.

Curing and processing research.

3. Studies should be made on the influence of drying on the composition of hops and their quality and marketability for brewing. Accurate chemical methods are needed to determine the changes which take place during the ripening and drying of hops. Temperature, atmospheric humidity, and final degree of drying are important factors to be considered, as well as the design of improved drying equipment.

4. Sulfuring processes should receive attention, and these studies should be extended to include the improvement and application of chemical methods in hop evaluation for brewing purposes. Present methods lack the much desired degree of exactness or definiteness from a chemical point of view, although an increasing use of chemical tests is being made.

5. The constituents of hops which impart flavor and aroma, and those having preservative properties should receive special study.

6. Studies on certain physical properties such as color, which may indicate improper drying, and age of the hops, both of which may affect quality, are also important to the brewer.

Fundamental chemical research.

Investigations of a fundamental nature are required to aid in the advancement of applied research which has for its objective the improvement of processing technique in the preparation of hops. This research will be primarily concerned with the nature of the resins, tannins, and essential oils. Many of the compounds found in hops, including alkaloids, which are now lost in the brewing process have potential value in other industries. Some of these substances are not found in other plant material.

7. Separation and pure science studies on the hard and soft resins of hops are fundamental to the brewing industry because certain of these are essential for flavor. The hard resins are largely insoluble and remain in the spent hops. The recovery of these and some of the undissolved soft resins from the spent hops offer a possibility for the development of potential raw materials for new industrial uses.

8. Substances of the nature of alkaloids, some with narcotic properties, are reported to be present, but their identities have not been adequately determined. A study of these is suggested.

9. The separation of the essential oil and studies of its characteristics are important. This oil is largely volatilized in the brewing process but is associated with the aroma of hops and hence is of considerable importance in the flavor of malt beverages.

10. Development and manufacture of hop extracts which can be carried over to meet seasonal fluctuations in the production of hops have been urged. Such a preparation would probably possess blending possibilities not practicable at present.

11. Investigations should be carried out on the possible uses in medicine of the various constituents of hops, particularly those of a narcotic or alkaloidal nature. Some of the bitter substances found in hops, such as humulon and lupulon, are not found in other plant materials, and these may find value for other purposes than in brewing.

12. Chemical studies on (1) the fibers of extracted residues; (2) the separation, identification, and utilization of hop-seed constituents; and (3) the possible recovery of such substances as dyes, tannins, wax, and pectin might prove fruitful.

DAIRY PRODUCTS

In the United States over 100 billion pounds of milk containing 13 billion pounds of solids in the form of fats, proteins, carbohydrates, and salts are produced annually. This has a value of about 2 billion dollars or about 20 percent of the total farm income, and approaches the combined value of cotton, wheat, and tobacco.

Three quite distinct geographic regions in the United States may be distinguished as milksheds in which the milk problems differ, superficially at least, and which must be approached from different angles. One includes Pennsylvania, New York, New Jersey, Maryland, and the New England States, in which the milk is produced primarily for direct consumption and manufacturing is a minor interest. The second is the Midwestern States, especially Wisconsin, Minnesota, and Iowa, in which the great bulk of the milk goes into manufactured products. The Pacific Coast States form a third region, based not so much on a difference in interests as on geographical isolation and climatic conditions. Conditions in this area are similar to those in the North Central States except that there are small sections of very intensive production and the proportion of byproducts now used in manufactured products is greater.

In the eastern region the primary interest is to increase the consumption of milk or otherwise extend the markets for milk at fluid milk prices. Of secondary interest is the production and distribution of butter, cheese, and other manufactured products by the best available methods. The surplus in the eastern fluid milk area is quite different from those of the more distinctly manufacturing midwestern and western sections. In the fluid milk areas, the demand varies with the seasons and to some extent with weather conditions, and especially with economic conditions which affect the purchasing power of the consumer. Even with a uniform demand it is impossible to adjust production exactly to consumption, and there is, consequently, a serious seasonal surplus. It will be necessary to further develop products, and particularly the more stable byproducts which can be made in varying volume, so that the returns from this surplus milk will approach as nearly as possible those from fluid milk. At this point the interests and the method of attack are identical for the fluid milk and the manufacturing areas.

Consumption.

Forty percent of the milk produced is consumed directly as such or as cream, and 4 percent is consumed as human food after concentration and sterilization to make evaporated milk. An additional 40 percent of the total milk supply is separated to obtain cream for butter making. Skim milk thus obtained, combined with that derived from milk in the separation of cream for direct consumption and for ice cream, makes a total of nearly 46 billion pounds annually. In addition to this enormous quantity of skim milk, the manufacture of creamery butter produces each year about 2.5 billion pounds of buttermilk, having approximately the same composition as skim milk. For the manufacture of the 650 million pounds of cheese produced annually over 6.5 billion pounds of milk is required; as a byproduct 5.8 billion pounds of whey containing 380 million pounds of lactose, protein, and salts is obtained.

In the 54 billion pounds of byproducts produced with the major dairy products there are 4.7 billion pounds of nonfat milk solids; that is about 36 percent of all of the milk solids produced in this country. These solids are in suitable form for human food except that in their natural form they lack palatability, are rather dilute, and are perishable. The individual constituents include casein, a highly complex protein having physical and chemical properties which make it almost indispensable in certain industrial processes; lactose, a sugar which possesses valuable unique characteristics; numerous salts of probable value in nutrition; and all the vitamins of the milk except the vitamin A.

The following statistical flow-sheet of milk shows the various purposes for which milk was utilized during a typical year together with the amounts of the various derived manufactured products.



In order to indicate briefly and concisely the situation in the United States with respect to exports and imports of dairy products, there is given below a table from the 1939 Agricultural Outlook Charts on Dairy Products, by the Bureau of Agricultural Economics of this Department. This table (23) shows that during the last 30 years, with the exception of the World War period, imports of dairy products have exceeded exports. The most persistent trade is in imports of foreign types of cheese. Imports of butter have been a relatively large part of total imports when domestic prices have exceeded foreign prices by more than the tariff rate. Fresh milk and cream imports from Canada were relatively large during the 1920's. Since the World War period exports have been primarily concentrated milks, but, in recent years, exports of these products have declined.

TABLE 23.—*Dairy products: Excess of exports or imports (milk equivalent) 1900–1938*

[Excess of exports—; excess of imports+]

Year ending June 30	Butter	Cheese	Concentrated milks ¹	Fresh milk and cream ¹	Total
	<i>Million pounds</i>	<i>Million pounds</i>	<i>Million pounds</i>	<i>Million pounds</i>	<i>Million pounds</i>
1900.....	-383	-352	+1	-----	-734
1901.....	-486	-247	+1	-----	-732
1902.....	-327	-105	+1	-----	-431
1903.....	-183	+15	+1	-----	-167
1904.....	-222	-8	(¹)	-----	-230
1905.....	-199	+128	(¹)	-----	-71
1906.....	-570	+106	(¹)	-----	-464
1907.....	-254	+164	(¹)	-----	-90
1908.....	-119	+239	(¹)	-----	+120
1909.....	-112	+285	+1	-----	+174
1910.....	-38	+378	-29	+66	+377
1911.....	-81	+351	-26	+210	+454
1912.....	-107	+401	-45	+101	+350
1913.....	-51	+467	-33	+112	+495
1914.....	+86	+612	-4	+160	+854
1915.....	-130	-55	-8	+187	-6
1916.....	-269	-146	-318	+107	-626
1917.....	-553	-517	-542	+67	-1,545
1918.....	-335	-346	-1,122	+64	-1,739
1919.....	-622	-164	-1,595	+97	-2,284
1920.....	-136	-45	-1,326	+104	-1,403
1921.....	+535	+55	-289	+155	+456
1922.....	+40	+266	-176	+199	+329
1923.....	+113	+459	-94	+239	+717
1924.....	+495	+625	-473	+359	+1,006
1925.....	-44	+516	-394	+483	+561
1926.....	+11	+580	-280	+496	+807
1927.....	+113	+856	-233	+527	+1,263
1928.....	+11	+722	-219	+480	+994
1929.....	-14	+817	-257	+327	+873
1930.....	-16	+757	-258	+250	+733
1931.....	-21	+561	-262	+85	+363
1932.....	+5	+556	-203	+12	+370
1933.....	-8	+545	-109	+5	+433
1934.....	-14	+457	-108	+2	+337
1935.....	+454	+471	-122	(²)	+803
1936.....	+100	+482	+33	(²)	+615
1937.....	+293	+646	-66	+8	+881
1938.....	+33	+542	-114	+7	+468

¹ Beginning July 1, 1936, skimmed milk and buttermilk are not included.² Less than 500,000 pounds.*Surplus.*

As milk and milk products are perishable, a surplus, in the sense that there may be a large carry-over from a period of flush production beyond the next one, does not exist. When the industry approaches a flush season with abnormally large quantities of butter, cheese, and other manufactured products on hand, prices are adjusted to stimulate demand. However, there are serious seasonal surpluses which, in their economic effects, present a challenge in the improvement of the dairy industry of this country.

The products made from milk differ so much in their nature, methods of manufacture, and uses to which they are put that each one has its peculiar problems. The following divisions have been provided as a matter of convenience: Milk and Cream for Direct Consumption, Butter, Cheese, Ice Cream, and Milk Byproducts.

MILK AND CREAM FOR DIRECT CONSUMPTION

Impact of recent technological advances.

Within a comparatively few years a very complicated and expensive system of milk distribution has replaced the farmers' wagons, the drivers of which dipped milk from cans into receptacles furnished by the customer. Demands of the consumer for better flavored milk, safer milk, milk that will keep longer, sanitary containers, and more frequent delivery, has added to the complexity and expense of getting milk from the producer to the consumer.

The city milk plant now represents a very large investment and requires frequent remodeling and replacement to keep abreast of the rapid improvements in technique and equipment. Milk-handling equipment is vastly better than that in use only a few years ago, but the cost is also markedly higher. Wages of milk-plant employees have advanced, and duplication of service and facilities is frequent. All this has tended to widen the spread between what the producer gets for the milk he sells and what the consumer pays for what he buys. This tends to cause discontent among the producers, who think that the wholesale price is too low, and to decrease consumption by those who think the retail price is too high. A relatively small reduction in the retail price would undoubtedly result in increased consumption and a corresponding reduction in surplus.

A major problem in this field is a reorganization of the system of city milk distribution on the basis of recent advances in transportation, refrigeration, concentration, and sterilization. The present system was developed at a time when milk was moved in cans by horse-drawn vehicles or by rail, refrigeration was by means of natural ice, and pasteurization and sterilization was hardly known outside the laboratory. Research work has been almost entirely on details of the present system, but it should now be possible to put the entire system on a basis which will use, to the fullest extent, the recent advances in knowledge and materially reduce the spread between the farmer and the consumer. It is evident, for instance, that an improvement in the process of sterilization, making it possible to place in grocery stores evaporated milk which could be reconstituted to a milk having the flavor of fresh milk, would revolutionize the milk-distributing industry.

Another major problem in this field is the development of orderly methods of utilization of the surplus milk resulting from the unbalanced supply and demand in the city milk areas. New York, for instance, has its daily demand and supply nearly in balance in December at 10 to 12 million pounds. In June a demand of 12 to 13 million pounds for milk and cream, with a supply of 21 to 22 million, exists. Thus the daily June surplus is about 100 percent of the December requirements. Fluid milk demand has a seasonal variation of only plus or minus 1 million pounds per day, but the requirements for cream, expressed in terms of whole milk, normally increase from about 3 million pounds to 4 or 5 million pounds in June. Making allowances for these variations in demand, the daily surplus of whole milk in the New York milkshed increases from 1 to 2 million pounds in December to about 10 million in June. In addition to the surplus of whole milk a large surplus of skim milk from milk separated to cream exists, and this varies within wide limits.

While some adjustments may be made in time through regulation of feeding and freshening, the main problem is to find means of converting this surplus milk into marketable products whose manufacture and sale can be adjusted to the extremely variable supply of raw material. This involves work on the manufacture of primary products like butter and cheese and some form of utilization of the skim milk, buttermilk, and whey, which come from these products, as well as the skim milk from the separation of milk for cream for table use and ice cream.

BUTTER

Importance of butter in the dairy program is indicated by the fact that over 1.6 billion pounds are produced annually. Butter holds its preeminent place in competition with other fats mainly because of its palatability, ready digestibility, and vitamin A content. In commerce, palatability or flavor is of chief consideration. The primary cause for inferior flavor in butter has been shown to be its manufacture from inferior quality cream—cream which is so sour as to require partial neutralization of the acid, and sometimes renovation to remove foreign flavors and odors. Butters made from such creams are not only of inferior flavor but deteriorate rapidly in storage and command a lower price than do those from sweet creams. Butter made from sweet cream has a clean, wholesome flavor, which it retains over a relatively long period of storage.

The major problem of the creamery industry is to replace the butter of mediocre quality with butter of desirable flavor freshly made from sweet cream. This can be accomplished by returning to the system under which whole milk was delivered to the creameries for separation; and this will be done when the farmer can be paid enough to make it more profitable for him to bring the milk to the factory than to separate the cream at the farm and feed the skim milk to the livestock. This situation can be realized when milk byproducts command a sufficiently better price because they are more efficiently utilized.

CHEESE

By far the most popular cheese, from an economical standpoint, is Cheddar or American cheese, which makes up 76 percent of the domestic production. It is made in relatively small factories, although the present tendency is toward larger units. The large proportion of the cheese is inferior in flavor and is stored at low temperatures and sold with little real ripening. This counteracts the tendency to develop a sharp flavor characteristic of the high-moisture cheese generally made. Part of the inferior quality is due to the low grade of milk delivered to many of the factories. Moreover, insufficient information is available on what standards should be applied or where the line separating satisfactory milk from unsatisfactory milk should be drawn. The quality of the cheese is evidently still further injured by lack of control of the manufacturing process.

Swiss cheese is also made extensively in this country, but the average grade is inferior to the imported, of which we receive only the best. Limburger and Brick are made quite extensively, and a number of other varieties are made on a small scale. Cottage, Philadelphia Cream, and other cheeses of this type are made very generally, especially in the city milk districts.

About 60,000,000 pounds of cheese (about 10 percent of domestic production) are imported each year which, if it could be made in this country, would provide a market for the milk of 135,000 cows. Some of this cheese is brought in at a price so low that it cannot be made here profitably under present conditions. The hard Italian cheeses, which are the most important in volume, might be made if the means of financing the long storage were available, although there is reason to believe that other factors may also be important.

Per capita consumption of cheese in this country is lower even than in England, which is notably a meat-eating country. If the annual per capita consumption could be increased by one pound, a market would be created for all the surplus milk on the Atlantic seaboard. Greater consumption can be obtained by producing a more uniform grade of distinctively flavored Cheddar and by developing new cheeses on the order of some of those now imported. Education will necessarily be an important factor in increasing consumer demand, especially for new products.

ICE CREAM

Production of ice cream in commercial factories is now approximately 250 million gallons annually. This great volume has been attained in a comparatively few years and has been accompanied by very rapid changes in the technique of manufacture as well as in the business of obtaining and storing the perishable raw materials and distributing the product.

Ice-cream makers have been much concerned over the question of maintaining a supply of cream, or its equivalent, and of nonfat milk solids to take care of the great variations in the demand for ice cream. There is not only a wide seasonal variation but a rise and fall from day to day as weather conditions change.

MILK BYPRODUCTS

The great economic loss in the byproducts, skim milk and whey, is through inefficient utilization, rather than by actual wastage. The great bulk of the skim milk is fed on the farms and is only potentially available for manufacturing purposes. Of the skim milk in creameries or milk plants over 700 million pounds are used in the making of cottage, pot, and bakers' cheese, 4 billion pounds in dried skim milk, and 1.7 billion pounds in cultured buttermilk and other beverages. Nearly all buttermilk is fed to farm animals either in its natural condition or in a semisolid or dried form. The 46 million pounds of casein made in 1936 required for its manufacture 1.6 billion pounds of skim milk. Considerable quantities of whey are actually wasted, but this situation is rapidly changing. The greater part is now fed to animals, about 1 billion pounds being dried annually for use as a constituent of proprietary feeds. About 120 million pounds of whey are used annually in the manufacture of lactose, and about 5 million pounds are fermented annually to make lactic acid.

Very little of these byproducts is available in large volume at any one place, but there are many centers of production where either skim milk or whey could be concentrated at one point without prohibitive expense. The wide seasonal variation places definite limits on the type of manufacturing process which can be operated profitably. Any new method of utilizing byproducts must be able to compete with

present uses and place a sufficiently high price on skim milk to induce farmers to bring whole milk to the creameries for separation.

LACTOSE AND LACTIC ACID

Lactose is a sugar composed of one molecule of glucose and one molecule of galactose. Apparently milk is the only natural source of lactose. It is present in normal milk in the proportion of over one-third of the solids and is the major constituent of many by-products. On account of its relative insolubility and lack of sweetness, it has found little place in foods except those especially prepared for infants. Because of the huge potential resources available, it is attracting industrial interest. Several methods of separating the lactose from whey and even from skim milk are available. The most obvious new use of lactose is through fermentation to lactic acid, which can be done economically. This process is in actual operation in one plant. The presence of two functional groups, one alcoholic, the other acidic, is the basis of much of the research on new derivatives of lactic acid.

PROTEINS

The milk byproduct casein is an important industrial protein material. There is included in this section a general discussion of proteins from all sources and, under the appropriate headings below, the fundamental studies on proteins now being carried on and those suggested. Much of the basic information obtained from these studies will be applicable to casein.

Proteins are essential constituents of every living cell, both plant and animal. Their functions in nature are manifold and varied in character. In living processes they serve as catalysts for carrying out physiological reactions, as sources of energy, and as units for structural purposes. In plants, in addition to their functions in the living cell, they form with carbohydrates and oils, the vast reserves of food laid up in storage organs for future growth. The storage proteins are especially abundant in legume seeds, in cereal grains, in nuts, and in the kernels of fruit pits. Animal proteins are especially abundant in blood and muscle, in skin, hair, and feathers, in hoofs and horns, and in milk and eggs. At times proteins may assume pathological significance, as in the viruses that cause both plant and animal diseases. In recent years, proteins such as casein, which can be secured cheaply in large quantities, are becoming increasingly important as raw materials for the manufacture of plastics, water paints, paper sizes, adhesives, etc.

Amino acids, which possess both acidic and basic groups, are the simplest building blocks of proteins. More than a score of different kinds of amino acids occur in proteins, and they are united in the protein molecule through the acidic and basic groups by the elimination of water. Proteins may contain from several hundred to several thousand of these groups. Changes in the combinations and arrangements of the amino acids give rise to dissimilar proteins, and as might be expected a very large number of different proteins are present in nature. Proteins isolated from the same kind of sources are identical; for example, blood proteins from different breeds of cattle are the same although blood proteins from different species of vertebrates are unlike. Generally, the more complex the organism the greater is

the variety of proteins present. Some of these occur only in minute amounts, as the enzymes which have specialized functions, whereas others are found in relatively large amounts, as the muscle proteins. Depending upon the organism, synthesis by physiological processes produces proteins in different forms—globular, planar, fibrous, or crystalline. The limited number of methods available for investigating proteins and the complexity of these substances have acted as obstacles in attempts to secure a more fundamental knowledge of their structure and properties. Because of their known properties, this class of compounds is attracting considerable interest industrially.

Tremendous quantities of proteins are available for possible industrial uses. Some indication of relative amounts of vegetable proteins from certain crop plants and their products, as compared with milk protein, is given in the following tabulation:

Source:	Percent- age of protein	Source:	Percent- age of protein
Milk (solids).....	26-28	Alfalfa leaves.....	24-26
Corn meal.....	7-10	Linseed meal.....	33-36
Wheat flour.....	10-14	Soybean meal.....	41-48
Rolled oats.....	9-12	Cottonseed meal.....	41-46
Alfalfa stems.....	11-13	Peanut meal.....	42-50

Animal products are even richer source materials. Hoofs, horns, feathers, hair, and silk are practically 100 percent protein. Dried blood contains about 85 percent; fish meal, about 50 percent; tankage, from 36 to 60 percent; fresh bone, about 20 percent.

Among animal proteins, casein, wool, silk, and gelatin are being used industrially. Zein and other vegetable proteins are also in commercial use. But the question as to what form of protein available in farm commodities is most feasible for industrial use from the economic standpoint is not yet settled.

Because of their importance and physiological interest proteins have received the attention of many investigators over a long period of years. They are probably being investigated to a greater extent now than at any time in the past.

PRESENT RESEARCH

Present research in the United States on milk and milk products relates to the utilization of these products in food, in feed, or in some industrial process. The first of these three types of investigations greatly outnumbers the other two. They are conducted by many agencies, but particularly by workers in Federal and State laboratories. Interest in the utility of milk byproducts in industrial processes has caused several private agencies to carry on pertinent research projects.

Research work under way has been classified under the following main headings: Fundamental Research on Milk; Milk and Cream for Direct Consumption; Butter, Cheese, Ice Cream; Milk Byproducts for Food and Feed Use; Milk Byproducts for Industrial Purposes; Fundamental Studies on Lactose; and Fundamental Studies on Proteins.

Fundamental research on milk.

1. Studies on milk as a physicochemical system including acid-base equilibria, physical equilibria or colloidal properties, coagulation, and the effects of freezing.

2. Investigations on the distribution and growth of bacteria in milk, their metabolism, and the influence of various physical and chemical factors on these organisms.

3. Nutritional investigations on (1) the factors which influence the vitamin content of the milk both before and after processing; (2) the composition of the fat; (3) the food value of butterfat in itself and in combination with other milk constituents, and (4) the role of milk minerals in human and animal nutrition. The nutritive value of constituents of milk is being compared with that of fats, carbohydrates, proteins, and minerals from other sources.

Milk and cream for direct consumption.

Research in progress on milk and cream for direct consumption is indicated briefly as follows:

4. Effect of various types of pasture, forage, hay, and ensilage, especially some of the newer plant introductions, on milk production and on quality as determined by odor, color, flavor, and physical and chemical analysis.

5. Similar studies, based on feeding byproducts of the fruit, vegetable, and oil-processing industries.

6. Effect of feeds and other factors on flavor of fresh and several-day-old milk. Special attention is given to the causes and prevention of what is commonly known as an oxidized or cappy flavor. Numerous other flavor defects are receiving attention.

7. Curd tension investigations leading to a greater knowledge of how to obtain a soft-curd milk by regulated feeding of the dairy cow, or by treatment of the fresh milk by mechanical means, by base exchange, and other methods.

8. Homogenization studies of milk and cream whereby greater subdivision and more even distribution of the fat is obtained. Related to these experiments is control of the flavor, lowering of the curd tension, and the "cream plug" problem.

9. Studies designed to improve methods by which the vitamin D content can be increased. Irradiation and other means for increasing the vitamin D content of milk are under investigation, such as the effect of various feeds and the addition of vitamin D rich substances to the milk.

10. Packaging studies in regard to the preparation of milk and cream for market. The advent of paper containers has given rise to many public health and economic problems.

11. Storage studies on cream, including preservation by freezing so that it can be carried over from a period of surplus to one of scarcity.

12. Studies on condensed or frozen condensed products which have for their purpose the preparation and preservation of milk which will serve, by the addition of water, as a source of good market milk.

13. Evaporated milk investigations: Attempts to improve flavor and color and to standardize vitamin D content at a relatively high level.

Butter.

14. Investigation of butter flavor as influenced by various factors. Included in these studies are (1) the effects of various metals; (2) the degree of acidity of the cream following the addition of so-called "neutralizers"; (3) the presence of certain metabolic products of the bacteria in the cream, such as acetylmethylcarbinol and diacetyl;

(4) the addition of such products in butter manufacture; and (5) methods for the control of flavor and for improved keeping qualities.

15. Studies of the nutritional properties of butter. Such research has for its objective (1) the determination of the vitamin content, especially vitamin A; (2) the sparing action of the fat on certain vitamin requirements; and (3) the influence of various feeds on vitamin content.

16. Processing investigations on such projects as the control of micro-flora and extraneous matter in butter, variations in color, texture, composition, and keeping quality, and methods for determining the probable rate of deterioration.

Cheese.

Work in progress to increase technical information relative to the manufacture of cheese falls in the following groups:

17. Studies on initiation of fermentation processes in making the many varieties of cheese. Detailed information on the micro-flora of the raw or pasteurized milk to which starters are added is being obtained.

18. Pasteurization investigations of cheese milk as related to ripening and quality of cheese.

19. Studies on the control of the hydrogen-ion concentration during the manufacturing process and its relation to quality. This is an important factor, perhaps the most important, in determining the grade of the cheese, but the limits at any particular stage or the optimum rate of acid formation have not been established.

20. Development of methods for following chemical changes taking place during the ripening of cheese.

21. Cheddar cheese studies including: (1) The investigation of bacteria producing the characteristic Cheddar flavor; (2) manufacture from homogenized milk to control the leakage of fat when the cheese is exposed to high temperature; (3) packaging for distribution.

22. Swiss cheese investigations on: (1) The bacteriological grade of the milk; (2) the standardization of the composition of the milk; (3) the selection of propagation of the three types of bacteria essential to required flavor and texture; (4) the control of the pH at each step of manufacture; (5) the temperature and humidity of the curing rooms.

23. Bacteriological and chemical studies on Roquefort, Brick, and Bel Paese cheeses. Almost no work is being done on Limburger or the hard Italian cheeses.

24. Studies on the manufacture of new varieties of cheese.

Ice cream.

Much of the research work that is being done on ice cream is empirical in nature. Pressure for results on many practical problems has forced investigators to neglect the more fundamental questions. An ice cream mix is at the same time a colloidal suspension, an emulsion, and a solution of various salts, soluble proteins, and sugars. The great alterations in temperature of freezing and hardening change the solubility and concentration of the constituents in solution and consequently alter the physical properties of the mix. Many factors such as raw materials and their treatment, methods of manufacture, and treatment of the frozen product influence the quality of the finished ice cream. The roles that many of these factors play

in ice cream quality are well known by experience, others are little understood. The effects of all are becoming better known as physical methods for measuring the quality of the finished product are being developed.

Present research projects on ice cream include the following:

25. Quality of components of the mix with respect to flavor and the effect of these components on body and texture as determined by rather simple methods and, in a few cases, by well-developed scientific methods.

26. Studies on new stabilizers as compared with gelatin or with ice cream made without the incorporation of a stabilizer.

27. Investigations on the preservation of properties of products from which ice cream is made, such as butter, cream, and the various fruits that are used as flavoring agents.

Milk byproducts for food and feed use.

Nutritional studies, especially vitamin research, have established the food value of dairy byproducts. Current discoveries indicate that other essential dietary factors as yet unrecognized may be present in milk. Utilization of byproducts in food is nutritionally desirable and economically sound.

Human food provides a larger and more profitable outlet for dairy byproducts than does animal feed. The development of efficient spray-drying equipment has made economical preparation of high grade dried products possible. The most striking illustration of the successful use of byproducts in foods is found in the rapid increase in the use of dried skim milk in bread making, which has grown in a few years to nearly 150,000,000 pounds. Skim-milk solids are also used extensively in ice cream, where superheating has been found to improve body. Utilization of whey solids in human food has not received much attention until very recently. Whey bread has now been shown to have a marked improvement in volume and appearance over water bread. Whey solids have been successfully used experimentally as an important constituent in candy, and they have been found suitable for incorporation in soups, beverages, and certain desserts. Vinegar has been produced by controlled fermentation of fresh whey.

For many years skim milk, buttermilk, and whey have been used for animal feeding. Development of cheap methods of water removal, especially drum drying and vacuum evaporation, has increased the use of byproducts in animal feed. The principle of acid preservation was applied in the development of concentrated sour skim milk; further, whey has recently been added to silage to accelerate the lactic acid fermentation. Pigs, calves, and chickens have been benefited by inclusion of milk byproducts in their diet, and this field is being extended to domestic pets and hatchery fish.

Present research on the utilization of milk byproducts for food and feed use includes the following:

28. Food studies, such as (1) improvement in equipment and processes designed to produce improved products from the standpoint of stability and salability; (2) incorporation of solids from skim milk and whey in food products; (3) improvement of packaging to facilitate the retail distribution of dry skim milk; (4) assay of the nutritive value of skim milk solids and the economy of these solids as a source of food essentials; (5) determination of the fate and function of

lactose in the human system and the role of lactose in mineral metabolism.

29. Feed studies including (1) determination of relative value of skim milk solids, especially of the minor constituents, for poultry and animals; (2) incorporation of milk byproducts in the form of buttermilk and skim milk solids in dairy, poultry, calf, and dog feeds.

Milk byproducts for industrial purposes.

While the use of milk byproducts for industrial purposes has not attained the commercial importance of milk byproducts in food and feed, interest in this subject has been greatly stimulated in recent years. Most of the research in this field has been directed to new and improved uses of casein and lactose. Much effort is being directed to improved methods of utilizing whey, especially through fermentation of its chief constituent, lactose.

Casein: A great deal of fundamental research on casein has been done but, principally because of the complexity of the casein, much of this research has been only partially successful. For example, the approximate molecular weight of casein is known and the proportion of its components is established, but the structural arrangement of these components has not been definitely determined. Lack of adequate fundamental information on casein has hindered development of its utilization.

Research on the manufacture of acid-precipitated casein has led to methods of producing remarkably pure casein commercially. Methods for use of this type of casein for paper coating, glue making, and related purposes have been fairly well standardized, and the basis for specifications for casein is available, though not uniformly applied. Efforts to produce a buttermilk protein that approximates skim-milk casein in its adhesive characteristics has been unsuccessful. Casein paints have been improved considerably in recent years, and the successful use of buttermilk protein in paint has been developed. Probably considerable further advances will be made in casein paints. Casein fiber has been developed commercially in Europe. Research on casein fiber in this country has led to several processes, some of which are now in the semiplant development stage. Little of this casein fiber research has been of fundamental nature; consequently much laboratory investigation is necessary to put this development on a sound scientific basis. Casein sheets for wrappings were made commercially for a short time several years ago. Since production was discontinued, further research has been done, and it is claimed that commercial production of an improved casein sheet is imminent. Here again fundamental research has lagged behind development.

Very little information is available on recent accomplishment in research on rennet casein or on the casein plastics made therefrom. The development of molded plastics from soybean protein indicates one direction research in this field might take. Some derivatives of casein have been prepared, but, with the exception of chlorinated casein and a few medicinally used compounds, no uses of such derivatives have appeared. Of the amino acids to be derived from casein, only glutamic has so far found commercial use; possible therapeutic and nutritional uses of others have received some attention, but so far without much success.

Lactose: The fundamental organic and physical chemistry of lactose has been rather extensively investigated. Its oxidation and reduction

products have been identified, its structure and its physical forms are well understood, and most of its physical constants have been determined. Additional work, however, remains to be done before a complete understanding of its properties can be obtained. Besides the commercial process for making lactose, there are available several newer processes which offer definite advantages of lower cost. In two of these, the lactose is a byproduct of a dairy operation. Development of these processes is dependent on the demand for low lactose skim milk and for riboflavin concentrates to a greater degree than that for lactose.

The lactic acid fermentation of lactose has been developed to commercial production. Cheapness of whey and rapidity of fermentation make this conversion of lactose economically possible. In other fermentations, such as that yielding citric acid, other sources of carbohydrate have been shown to have advantages over whey. The propionic acid fermentation of whey has been shown to be a possible but uneconomical method of lactose utilization. Greater utilization of lactic acid as a means of greater utilization of lactose has had attention only recently. Present uses are in acid beverages, in the tanning industry, and in phenol-aldehyde resins. Of the derivatives of lactose, only lactose nitrate has been shown to have possibility of commercial use. Its characteristics as an explosive have been determined, but it has not been developed commercially.

Other components: The nutritional value of the riboflavin and the whey proteins of milk have been investigated. A method of preparing a highly concentrated riboflavin from whey has been devised, and the product is being marketed. Research for producing low ash, undenatured whey protein has met with little success in the past, but current research is more encouraging.

Research now in progress on milk byproducts, including fundamental studies on proteins, is summarized below. Very little fundamental work is being done on lactose. What is being done is of the general type outlined in the section, Fundamental Studies on Starch, Starch Derivatives, and Sugars, in the chapter on Corn.

Lactose and lactic acid.

30. Methods of preparing lactose from milk byproducts. A method is being studied by which it is possible to extract concentrated whey or whey powder with alcohol and obtain lactose in pure form with one recrystallization. The soluble proteins in undenatured form and vitamin-rich residue remain. This method is still in the laboratory stage.

31. Studies of methods of obtaining lactic acid from whey by fermentation.

32. Dehydration of lactic acid esters to form acrylic esters for use in the preparation of the important acrylic acid type plastics.

33. Studies of the utilization of various lactic acid derivatives as solvents.

Casein.

34. Studies on casein-manufacturing methods as related to the properties of casein and utility of the commercial product, whether it be in the coating of paper, the preparation of glues, plastics, paints, fibers, or other industrial materials. Research is being conducted on

the recovery of casein from buttermilk and the use of casein from this source in paints as compared with casein derived from skim milk.

35. Casein-paint investigations with the object of decreasing odors, mold susceptibility, and other factors which reduce their utility.

36. Studies on casein sizes for coating paper and the use of casein as a spreader and adhesive in insecticides and fungicides.

37. Casein plastics: Investigations designed to decrease the time necessary to prepare the plastic and to improve the product, especially with regard to its water resistance.

38. Casein sheets: Development of methods of making improved transparent sheets resembling cellophane.

39. Casein fiber: Investigations on the preparation of artificial wool fibers.

40. Casein derivatives: Various derivatives are being prepared, and their industrial uses are being investigated. These investigations may have considerable bearing on some or all of the casein products mentioned above.

41. The separation of albumin from whey in a water-soluble, undenatured form.

Fundamental studies on proteins.

Present research on proteins is fairly evenly divided between nutritional and chemical studies. A large part of the progress in the field of chemistry is being made on proteins of physiological and pathological interest, as the enzymes and viruses. Relatively much less attention is being devoted to the common proteins present in agricultural commodities. In particular, this class of compounds requires attack by employment of the newer technologic improvements which have been so successful in advancing our knowledge on enzymes and viruses. Information collected in the Survey has been classified under the following headings:

42. Agricultural research: (1) Scattered studies on the protein and amino-acid content of different varieties of wheat and corn. Significant differences are being found. (2) A broad program on the determination of the amount of protein present in different varieties of soybeans grown under varying soil, climatic, and nutrient conditions.

43. Isolation, fractionation, and purification: (1) Improved methods of preparing the whole protein from cow and goat milk, corn, soybeans, solvent-extracted cottonseed meal, eggs, etc., by means of solvents such as water, 70 percent alcohol, and various salt solutions or precipitating agents such as acids. These studies are of both fundamental and practical significance and have as their aim the extraction from the source material of the maximum amount of the protein content. (2) Solvent studies are in progress for the isolation of specific proteins. A tremendous amount of work is being carried out on the preparation of enzymes, such as papain, lipase, catalase, peroxidase, carbohydrases, and urease, from agricultural commodities. Proteins of less direct physiological interest, such as lactoglobulin from milk, and glutelins from cereals, are receiving much less attention. (3) The use of the ultracentrifuge for the extraction of pathological proteins and enzymes from animal and plant juices. (4) Solvent, ultracentrifugal, ultrafiltration, electrodialytic, and absorption methods for the fractionation and purification of enzymes, hormones, viruses, and toxins.

The progress made in recent years in these fields is particularly striking. Purification of the albumin, lactoglobulin, and casein fractions from milk is being studied intensively. Casein is practically the only protein of the common ones present in agricultural commodities being attacked by such newly introduced tools as the ultracentrifuge. Comparatively much less work is being performed on the fractionation and purification of the proteins occurring in the cereal grains, legumes, oil seeds, etc. Fractionation studies are in progress on the preparation in the pure state of the glutelins of the cereals, wheat, oats, corn, rye and sorghum, and the globulins of beans. The homogeneity of zein from corn is under investigation. Few of the common proteins have been isolated in the pure crystalline state.

44. Classification and identification: The system commonly employed for classifying proteins is a purely arbitrary one based on solubility and precipitability. Although the limitations of the system which had its origin in 1908 are recognized, relatively little research is being performed with the object of providing a clear understanding and differentiation of the various proteins. Revised or new methods for identifying proteins are receiving practically no attention.

45. Analytical: (1) Methods for determining the groups in proteins such as gasometric determination of amino and carboxyl groups, formol titration, determination of surface groups by oxidation, reduction, and enzymic estimation of amide groups are under active investigation. (2) Improved and novel colorimetric, gravimetric, and enzymic methods for estimating amino acids, particularly the nutritionally essential and basic ones, are being studied. Polarographic studies on the estimation of cystine in proteins are in progress. (3) Researches are being intensively pursued on the elementary composition and distribution of nitrogen in various proteins, on the estimation of various essential amino acids in staple foods, on the determination of amino acids and prosthetic groups in pure protein fractions, hormones, enzymes, and viruses, and on the determination of the basic and acidic amino acids of a number of important proteins.

46. Physicochemical: (1) Research on the development of new tools to be applied in the solution of protein problems is being conducted. (a) X-ray diffraction studies of crystalline proteins, leather, fibers, etc., are being made in order to secure structural information; (b) crystallographic data on crystalline proteins are being secured for identification purposes; (c) the ultracentrifuge, ultrafiltration, and electrodialysis are receiving broad application in the purification of enzymes and viruses and in the determination of their molecular weights. Parallel studies on casein are also under way; (d) optical rotatory, spectroscopic, polarographic, and magnetic moment measurements of a number of proteins are being made for analytical and structural reasons; (e) the colloidal properties and such physicochemical properties as solubilities, rates of diffusion and sedimentation, and oxidation-reduction potentials are receiving attention. The major portion of this kind of work is being conducted on enzymes and pathological proteins. (2) Studies of monomolecular and polymolecular protein films on water are yielding information on the shape of the molecule, on the active parts of enzymes, and on the subsidiary forces in the molecule. This work is being very actively pursued.

47. Amino acids: (1) Studies of the acidic, basic, and enzymic hydrolysis of a large variety of proteins or polypeptides to their constituent amino acids. Data on the distribution and number of

amino acids in proteins are being obtained. (2) Studies of methods for separation of amino acids or their derivatives. Molecular distillation, different solubility of salts, electro dialysis, etc., are current methods of attack. Older methods for separating amino acids are being refined. (3) Studies on the chemical and physical properties as well as on the synthesis of various amino acids.

48. Polypeptides: (1) Graded acidic, basic, and enzymic hydrolysis of proteins to polypeptides. (2) Methods of separating polypeptides and studies of their chemical characteristics. Pure polypeptides are being prepared synthetically and their behavior toward enzymes studied with the aim of elucidating the mechanism of specific enzyme action.

49. Polymerization: The only work on the polymerization of proteins is empirical in nature. Studies of this kind are described under the sections dealing with casein, soybean meal, etc. Some research is being conducted on the condensation of amino acids, di- and tripeptides to polypeptides.

50. Constitution: Studies of surface reactions, such as mild oxidation-reduction of enzymes. Controlled acetylation and diazotization of the surface of proteins is being effected in connection with antigenic studies. Studies already outlined in sections 45, 46, and 47 are being employed to determine the constitution of proteins.

51. Denaturation: (1) Since denaturation usually converts protein to a less desired insoluble and active condition most of the work in this field is of indirect character, and deals with studies in which denaturation is avoided rather than investigated. The nature and extent of changes in protein occurring in grains and seeds on storage are receiving attention. (2) Theoretical studies on the mechanism of denaturation.

52. Prosthetic groups: Scattered work on the prosthetic groups present in some proteins. Studies are being conducted on the composition of nucleic acid present in tobacco mosaic virus. Haemin and the prosthetic groups in the enzymes, catalase, and peroxidase are receiving some attention, mainly from the spectroscopic viewpoint.

53. Nutrition: A tremendous amount of work is being carried out on the nutritionally essential amino acids and the digestibility of proteins present in the staple foods and feeds. Such investigations are listed under the separate farm commodities.

SUGGESTED RESEARCH

Fundamental research on milk.

The following suggestions have been received for studies on problems relating to milk itself as distinguished from milk and milk products as articles of commerce and on other main phases of research on dairy products.

Suggested research has been classified as follows:

1. Chemical investigations to determine the ultimate composition of some of the glycerides; what the minor constituents are; the calcium-ion concentration in milk; the relations maintaining the stability of the solutions and suspensions.

2. Bacterial studies such as the relation of bacterial growth to oxidation-reduction potentials; antibiotic and symbiotic relations of bacteria; bactericidal properties of milk and their relation to the growth of special cultures in milk.

3. Nutritional studies of milk fat which have for their purpose a comparison between the nutritive value of milk fat and other fats; also the determination of whether milk fat has a sparing action in certain vitamin requirements or a special nutritive value in combination with food essentials which are not possessed by other fats.

4. Investigation of effect of low-temperature storage on milk flavors and bacterial growth. It may be possible to eliminate much of the machinery of city milk distribution by centralizing milk supplies in country plants.

5. Studies on factors controlling the germination and destruction of resistant bacterial spores. Further experimentation on pasteurization of milk by high-pressure fields and sonic vibrations has been suggested. The high-temperature sterilization, which gives evaporated milk its cooked flavor, is required to kill a very few highly resistant spores. If these could be eliminated or destroyed in commercial operations without appreciably affecting the flavor and color of the sterilized product, the influence on the dairy industry would be profound. In this connection the relation of methods and time of heating to changes in color, flavor, and stability is important.

Milk and cream for direct consumption.

The problem of simplification of the distribution of city milk and reducing its cost to the consumer involves a number of subsidiary problems, some of which have only an indirect bearing on the main problem.

Research problems which have been suggested are as follows:

6. Oxidation studies of milk constituents and their relation to the flavor of fresh milk, evaporated milk, milk powder, and cream. Any processing of milk is likely to introduce off flavors by catalyzing oxidations.

Butter.

7. Studies on the influence of various production factors, types of ration, etc., on the quality of butter have been suggested.

8. Creamery operators and others desire information on the influence of manufacturing processes on butter; on how to make butter that will be especially adapted to baking; on how to process cream so as to remove flavors and odors that adversely affect the butter; and on the preparation of a better commercial product from hard milk fat.

9. Further investigations on the keeping quality of butter, the cause and prevention of off flavors, improved packaging methods to preserve the natural flavor, and like problems.

10. Further studies on the nutritional value of butterfat.

Cheese.

Suggestions received have been grouped as follows:

11. Cheddar cheese studies, such as (1) development of a system of scientific control by which the manufacturer can regulate the quality of the milk and the manufacturing technique to secure a uniformly good product; (2) the effect of pasteurization on milk with the object of making cheese which will develop a normal flavor within a reasonable time; (3) development of a method of making cheese from homogenized milk which does not leak fat when exposed to high temperatures; (4) perfection of the method of ripening cheese in valve-vented cans so that it will be adapted to all classes of trade without undue increase in cost.

12. Swiss cheese studies, including (1) the determination of the optimum conditions for growing starter cultures, the organisms of which will maintain their ability to grow and to produce desired effects in the cheese; (2) the combination of strains which work together to give the required flavor and elasticity of the curd.

13. Studies to develop methods for making Parmesan and similar cheeses under domestic conditions, including study of chemical changes and bacteriological factors concerned in the ripening.

Storage.

14. Studies on cream, butter, butterfat, and other products to maintain a more uniform supply.

Ice cream.

Suggested research has been classified as follows:

15. The physics of freezing and hardening of ice cream: (1) Investigations with special reference to the use of the newer types of continuous direct-expansion freezers; (2) to ascertain the effect of quick freezing on the properties of ice cream; (3) to determine the effect of each ingredient on the properties of the commercial product.

16. Studies on the use of new dairy products in ice cream, such as low-lactose sweetened condensed skim milk and soluble whey proteins.

Milk byproducts in food.

17. Food studies which have been suggested are: (1) The determination of why a relatively large amount of dry skim milk can be successfully incorporated in bread in some instances but not in others; (2) the incorporation of dry skim milk, dry whey, and the principal constituents of these solids in canned vegetables, canned and dried soups, confectionery, and fruit desserts; (3) extension of old and development of new food uses.

Byproducts for industrial purposes.

The following problems have been suggested:

18. Investigations of new methods of separating, and constituents of skim milk, whey, and buttermilk: (1) To improve methods for recovering lactose; (2) to work out more economical methods for manufacturing casein; (3) to determine the standards of purity and quality of each byproduct based on the application to which it is put.

19. Lactose investigations, such as (1) extension of research in progress on the production of lactic acid, its esters, salts, etc.; (2) hydrolysis of lactose and means for utilizing the materials so made; (3) development of new uses for lactose and its derivatives.

20. Casein-fiber studies, including investigations on the many problems associated with the use of casein in the manufacture of wool-like fibers.

21. Development of methods for producing improved casein plastics.

Fundamental studies on lactose.

22. Suggested fundamental studies on lactose are similar to those described under the subject Fundamental Studies on Starch, Starch Derivatives, and Sugars in the section on Corn.

Fundamental studies on proteins.

Suggested fundamental studies on either nonfibrous proteins, fibrous proteins, or both, have been classified as follows:

23. Agricultural research: Effect of breeding and varietal differences, climate, growing conditions, maturity, nutrition, disease, and insect infestation, etc., on the kinds and relative amount of protein produced in plants, including the roots, stalks, leaves, flowers, fruits, and seeds; and in the animal body, including the skin and its appendages, the bony framework with attached musculature, the internal organs with their secretions, and the body fluids.

24. Isolation and purification: (1) Preparation of either unaltered or modified proteins by new or refined chemical or physical methods from hydrated or dehydrated materials by extraction with water, salt solutions, or organic solvents; (2) investigation of the possible change in state of proteins on isolation; (3) fractionation, purification, and crystallization by new and modern physical or chemical methods for preparation of homogeneous proteins.

25. Identification and classification: (1) Development of physical and chemical methods for identifying and characterizing the different animal and plant proteins or their constituents; (2) investigation of new and evaluation of old systems for classification of proteins.

26. Analytical: (1) New or improved colorimetric, gravimetric, or spectroscopic methods for quantitatively estimating proteins and the amino acids contained in them; (2) determination of the amounts of the various amino acids in proteins occurring in agricultural commodities.

27. Physicochemical: (1) Application of ultracentrifugalization, ultrafiltration, cataphoresis, electrodialysis, and diffusion methods for fractionation and purification of proteins or for the determination of their molecular size, crystallographic, X-ray, and spectroscopic methods, and in particular ultraviolet and infrared absorption methods for identifying proteins, and securing information on their compositions; (2) investigation of properties of monomolecular and poly-molecular surface films as related to the configuration and function of proteins (enzymes); (3) securing of exact data on the polar and colloidal properties, solubility, surface tension, viscosity, specific rotation, refractive index, etc., of various pure animal and plant proteins, polypeptides, and amino acids.

28. Decomposition to simpler units, amino acids, and polypeptides: (1) Complete and stepwise acidic, basic, and enzymic hydrolysis of proteins for preparation of amino acids, and of polypeptides having various mean molecular weights. (2) Separation of amino acids or modified amino acids and polypeptides by physical and chemical methods. Molecular distillation as a means of separating modified amino acids particularly seems worthy of attention. (3) Synthesis of and chemical investigations on amino acids and polypeptides. (4) Fission of proteins by new methods, and separation of products.

29. Polymerization: Development of methods for polymerizing proteins, polypeptides, or amino acids to fibrous or nonfibrous materials.

30. Constitution: (1) Controlled acetylation, methylation, diazotization, halogenation, oxidation, reduction, etc., of the normal protein molecules, including enzymes and monomolecular films; (2) subsequent appropriate modification to determine the number and kind

of active groups present on the periphery of the molecule; (3) investigation of various degradative and synthetic reactions and the utilization of this information in determining the number and the arrangement of the amino acids in the molecule; (4) employment of physico-chemical methods (see 27) and modern concepts in the elucidation of the spatial configuration and structure of proteins and the nature of the primary and secondary valence bonds.

31. Denaturation: (1) Effect of heat, light, solvents, acids, and bases on the primary and secondary valence forces in proteins and relation of dehydration to denaturation of proteins; (2) determination of active groups on surface and configuration of denatured molecules; (3) development of methods for reverting denatured proteins.

32. Prosthetic groups: Investigation of proteins (lactoglobulin, egg-white proteins, etc.) containing prosthetic groups, such as carbohydrates, nucleic acid, adenosine phosphate, and haemin, to determine the nature of the prosthetic group and type of binding with proteins.

POULTRY AND EGGS

The poultry industry of the United States is a widely distributed and diversified activity, poultry products being more generally produced than any other agricultural product. It is also one of the most important of the agricultural activities of the country providing protein types of food. In dollar value of production it is second only to the meat and dairy industries. The products of the industry are used almost exclusively as human food. To a limited extent byproducts also are used as foods; but at present many of the byproducts incidental to the preparation of foods are still merely wastes, or even have serious nuisance characteristics.

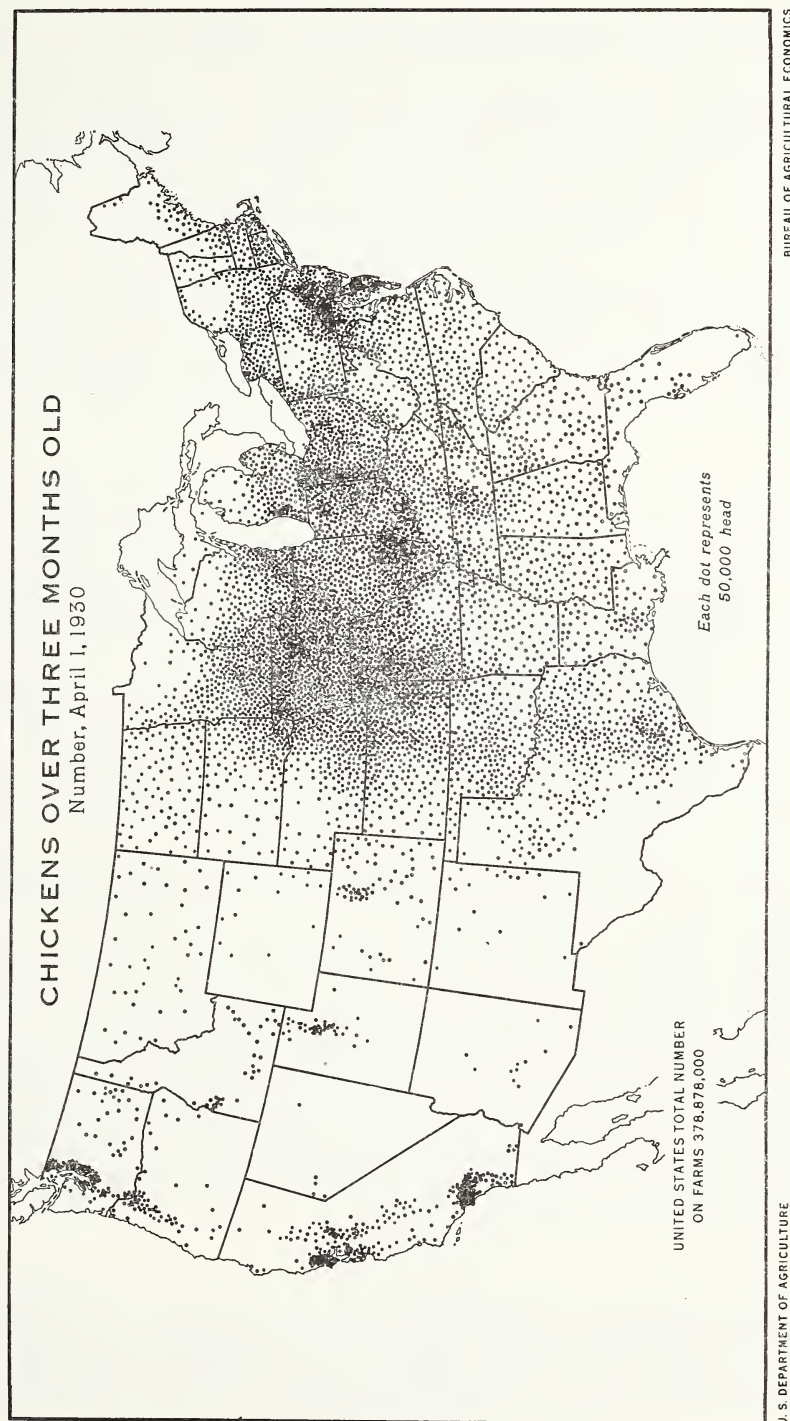
The kinds of poultry contributing chiefly to the poultry-meat supply of this country include chickens, turkeys, geese, ducks, guinea fowls, and pigeons, of importance in the order named. Because of the relatively greater number raised annually in the United States, chickens provide by far the largest part of the poultry meat and eggs consumed. It is in this field that significant surpluses and byproducts are found. While the following data are confined mostly to chickens and their eggs, any program of research developed around these two commodities would find immediate application to any of the other classes of poultry and their products and byproducts.

PRINCIPAL POULTRY PRODUCTS

CHICKENS

For many years the farm poultry industry of this country centered in and around the Corn Belt, the region of cheap feed. In more recent years, however, there has been a marked tendency to expand poultry production in specialized commercial areas, notably the Atlantic area adjacent to Philadelphia, New York, and Boston; the region surrounding the large industrial centers of the Midwest; the San Francisco and Los Angeles areas of California; and the Puget Sound area of Washington.

The high point in number of chickens on farms, about 475 million, was reached in 1928. The number had declined to about 387 million at the end of 1937, owing mainly to droughts, feed shortage, and low prices.



Of the total number of chickens on farms this year, about 180 million are in the North Central States. The North Atlantic States have 46 million chickens, while the South as a whole has about 123 million. During the last decade the South has maintained practically a constant proportion—30 percent—of the hens in the United States. The tendency in the West has been to reduce the number somewhat, while in the East the number has increased. Among individual States, the largest poultry population, 27 million chickens, is found in Iowa. Texas is next with 23 million, followed in order by Illinois, with 22 million; Ohio, 20 million; Missouri, 19 million; and California, 17 million. The size of the typical laying flock on American farms ranges from about 65 hens and pullets in September up to about 86 in January. Farm flocks were sharply reduced following the droughts of 1934 and 1936 but are again on the increase. These figures refer to general farm production and do not include commercial flocks. This specialized activity produces probably about 200,000 birds per season.

TURKEYS

The 1930 census showed four principal areas of turkey production in the United States. Texas was by far the leading producer, with nearly 4 million turkeys at that time. The second center of production was the Red River Valley of North Dakota and Minnesota; these two States have nearly $1\frac{1}{2}$ million each. The Pacific coast was an important production region, California having about $1\frac{1}{4}$ million birds. The fourth center of production was the Virginia-Maryland area, with well toward a million birds.

Recent unpublished estimates indicate that since 1930 the number of turkeys in the country has increased by about half. There have been important increases in the Northeast and in the central States of the Corn Belt. Heavy increases have occurred in Iowa, Missouri, and eastward to Ohio. The tendency has been toward some decrease in Texas and North Dakota, while the Pacific coast has added to its turkey population.

Estimates based upon prices and weights of recent years indicate that turkeys in the United States have a farm value well in excess of \$50,000,000.

The mid-November average price received by turkey raisers throughout the country has ranged from a high of 31 cents a pound in 1928 down to a low of about 12 cents in 1933. In recent years the November price has been about 15 to 20 cents a pound, live weight.

As to the current turkey situation, it was estimated that the number on hand September 1, 1938, was about 4 percent larger than in 1937. Producers this year (1938) have been favored by the lower prices of poults and of feed, a favorable growing season, and a comparatively small carry-over of turkeys and chickens in cold storage. The increasing tendency toward year-round consumption of turkeys also is favoring expansion in the industry.

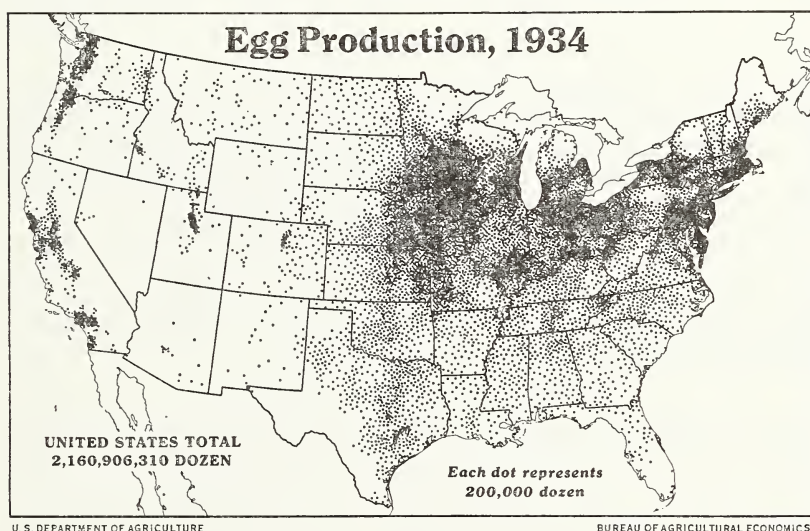
EGGS IN THE SHELL

The total annual production of shell eggs in the country is about $2\frac{1}{2}$ billion dozen. The gross income to farmers in the last 12 years has been about 600 million dollars a year from eggs and 350 million dollars from chickens. The number of eggs laid varies widely through

the different seasons of the year, normally from a low in December to the high point in May. The average production per hen is about 105 eggs a year.

Some idea of the utilization of the farm output of poultry products may be gained from the figures for a typical year, 1935. Of the total number of chickens raised that year, some 205 million were used on the farms, and 355 million sold. Similarly, of 2½ billion dozen eggs produced, some 750 million dozen, or 30 percent, were used on farms (100 million dozen for hatching and 650 million dozen otherwise used in the home), and 1¾ billion dozen sold.

The marketing movement of poultry products in the United States is toward the four great centers, Boston, New York, Philadelphia, and Chicago. San Francisco also figures as a fairly large center of poultry and egg receipts. In respect to eggs, average receipts at New York alone in recent years have been about 6¼ million cases of 30 dozen each. From 13 to 16 million cases of eggs frequently have moved from the country to these five centers of consumption in a year.



The Midwest is the most important source of eggs for eastern markets, but the East has been supplying an increasing proportion during the last 5 years. There has been a tendency for receipts from the Midwest and far West to decline. Over a 10-year period the proportion of eastern receipts in these markets has risen from 13 to 23 percent. The percentage from the far West, on the other hand, has dropped from 13 to 11 percent. The rise of the eastern poultry industry is one of the outstanding tendencies in the situation.

COLD-STORAGE STOCKS

The best clue to what may be called the seasonal surplus in poultry products is to be found in cold-storage stocks. Stocks of eggs in cold storage are accumulated during the months of heavy production, including March, April, May, and June. They are usually at their peak about August 1. Storage stocks are moved into consumption during the fall and winter, when production is low.

FROZEN EGGS

Since about 1916 frozen eggs have been making up a more and more important proportion of the supply of eggs in storage. This summer more than a third of such eggs were frozen-storage holdings equivalent to 6,407,000 cases of shell eggs and 3,867,000 cases of broken-out frozen eggs. It may be remarked that cold-storage holdings at present are the lightest since 1916.

A representative picture of storage holdings of eggs will be conveyed by table 24, in which shell and frozen eggs are combined, frozen eggs having been converted to a shell-egg equivalent.

TABLE 24.—*Shell and frozen eggs (shell-egg basis) in storage, 4 seasons, 1927-38*

Year	January	March	August	October
	<i>1,000 cases</i>	<i>1,000 cases</i>	<i>1,000 cases</i>	<i>1,000 cases</i>
Average, 1927-36.....	2, 723	1, 374	12, 096	9, 838
1937.....	2, 132	1, 305	13, 486	11, 293
1938.....	3, 951	2, 817	10, 278	-----

STORED POULTRY

In addition to eggs, a substantial amount of dressed poultry is held in cold storage. These stocks increase during the heavy marketing season in the fall and early winter, usually reaching their seasonal peak sometime in January. The outward movement of stocks takes place between January and September, so that the quantity in storage ordinarily reaches its lowest level sometime in August.

Taking the storage figures as of February 1, which is about the peak, the total stocks of frozen poultry in storage in recent years have ranged from about 100 million to 178 million pounds. Storage holdings of poultry of February 1, 1938, amounted to 115 millions pounds, a considerable reduction from the previous year.

TRENDS IN THE POULTRY INDUSTRY

As to the present status of poultry production, the industry is just staging a recovery following the depletion of flocks during the bad drought years, 1934 and 1936. It seems reasonable to expect that considerable expansion will take place in poultry flocks during the next year or two. It must be noted, however, that the increasing efficiency of egg production per bird makes it possible to increase the numbers with relatively fewer hens, which will tend to create a surplus.

The intensive poultry development on the Pacific coast has been meeting severe competition from other areas nearer the eastern markets in recent years. During the last 10 years the number of layers in the highly commercialized areas of the far West has shown a decline of 17 percent as compared with only a 2-percent decline in the similar commercialized section of the North Atlantic States. The low level of egg prices in recent years has made it difficult for western eggs to bear the cost of transportation to eastern cities. Also, the great improvement in quality of eggs in eastern regions has been a factor in the situation.

The most significant recent trend in the poultry industry has been toward large-scale commercial egg production. This development has been especially marked in the North Atlantic States. Commercial producers usually specialize in the production of eggs during the periods of normal scarcity. Apparently this trend is likely to continue.

The number of eggs laid per hen has been steadily increasing since the first census figures were obtained in 1880. This trend has been associated especially with the development of the large commercial flocks, reports indicating that the latter produce about 19 percent more eggs per layer than the average farm flocks. Virtually all this increase of production per layer in large flocks comes during the fall and winter months, thus helping to iron out the seasonal gluts and shortages.

MANUFACTURED PRODUCTS

According to data collected for the Biennial Census of Manufactures, the number of chickens dressed and packed has remained fairly constant since 1929, averaging about 325 million pounds, while turkeys dressed and packed have more than doubled, with a steady increase from 31.4 million pounds in 1929 to 73.5 million pounds in 1937 (table 25). Ducks, geese, and other poultry are holding their own, but show no spectacular increase, the figure for ducks for 1937 being approximately 5.9 million pounds, and that for geese, 3.7 million pounds.

In addition to the cold-storage supply of shell eggs, approximately 208 million pounds (178 million dozen) are broken out and frozen, either as whole eggs or separately as yolks and whites. Still a third egg product is available—dried egg material. It is possible to obtain dried whole egg, dried egg yolk, and dried egg albumen. At the present time most of the dried egg products are imported.

Quick-frozen poultry, a comparatively new item, has already reached a total production of more than 2 million pounds.

POULTRY BYPRODUCTS

Poultry byproducts are of two types—the slaughterhouse waste from cold-storage, canned, and quick-frozen fowl, and the incubator waste from commercial hatcheries. In full-drawn poultry, there is an estimated 25 percent waste. In quick-frozen birds alone this represents more than 1,600 tons of offal, largely concentrated at packing plants. Feathers constitute an important and troublesome item, with an exceedingly variable market (table 25).

TABLE 25.—*Amounts and values of poultry products in the United States, specified years*

	1937 ¹	1935	1931	1929
Poultry, dressed and packed:				
Total pounds.....	451,659,229			
Total value.....	\$97,332,316	\$90,333,714	\$93,131,759	\$122,466,372
Chickens: ²				
Pounds.....	330,190,937	306,316,832	342,037,719	329,689,483
Value.....	\$70,587,333	\$61,945,248	\$75,572,064	\$94,324,785
Turkeys: ²				
Pounds.....	73,575,237	45,236,127	35,638,496	31,427,113
Value.....	\$16,472,207	\$11,124,925	\$8,983,626	\$9,908,921
Ducks: ²				
Pounds.....	5,960,633	7,063,084	5,633,236	5,659,706
Value.....	\$1,152,105	\$1,369,760	\$1,097,787	\$1,385,853
Geese: ²				
Pounds.....	3,704,862	4,962,377	4,170,092	
Value.....	\$762,488	\$903,517	\$783,343	
Other poultry: ²				
Pounds.....	1,404,859	1,335,007	1,235,816	2,781,999
Value.....	\$340,924	\$282,993	\$291,952	\$654,984

¹ Preliminary figures.

² These figures are incomplete to the extent to which data for the specified kinds of poultry are included in the figures for "Poultry not reported by kind."

TABLE 25.—*Amounts and values of poultry products in the United States, specified years—Continued*

	1937	1935	1931	1929
Poultry, dressed and packed—Continued.				
Poultry not reported by kind:				
Pounds.....	36, 822, 701			
Value.....	\$8, 017, 259	\$14, 707, 271	\$6, 402, 987	\$16, 191, 829
Poultry, canned, value.....	\$2, 334, 639	\$1, 968, 923	\$2, 763, 845	\$3, 748, 475
Chicken, potted and deviled, value.....	\$59, 200	\$30, 000	\$38, 876	
Chicken broth and soup, and other soups, value.....	\$2, 239, 160	\$2, 187, 593		
Chicken and noodles, chicken à la king, etc., value.....	\$379, 166	\$548, 238	\$1, 871, 292	\$1, 360, 567
Feathers sold:				\$222, 766
Chicken:				
Pounds.....	1, 897, 403			
Value.....	\$85, 803			
Other:				
Pounds.....	706, 000	\$107, 097	\$121, 466	\$408, 324
Value.....	\$95, 998			

* Revised figures.

The waste from the 12,000 or more hatcheries, which have a total capacity of 325 million eggs at one time, amounts to at least 25 per cent of all eggs set, or a total of 10 million dozen infertile eggs and dead embryos. This represents a waste of at least 15 million pounds annually in the hatchery industry. In addition, at the hatcheries specializing in day-old chicks for laying flocks, thousands of baby cockerels are killed and thrown away.

PRESENT RESEARCH

Poultry.

Although of great economic importance, poultry-killing byproducts and eggs are so little understood that most of the research outlined will for some time necessarily be of an exploratory or preliminary nature. Research now in progress, with food as an objective, may be adaptable to nonfood industrialization of these materials, but most of the projects now under way in research laboratories as well as those which have been suggested to the Department do not give promise of immediate results on a developmental basis. This, in part, accounts for the fact that poultry and eggs are not one of the commodity groups designated for initial attention at the regional laboratories, but much of the fundamental work of these institutions will have a direct application to materials which may be recoverable from these sources. Thus a basis will be laid for a service to these commodities as well as to others receiving primary attention. Fundamental work done on proteins of other agricultural products will find a ready application to similar studies on the proteins of eggs.

Poultry research now being done by both Federal and State agencies deals largely with breeding of birds for better meat or egg-laying characteristics, disease control, and the nutrition problems involved in poultry feeding. To a lesser degree research by official agencies deals with the characteristics of the dressed birds as food or with the preservation of poultry in storage. Recently quick freezing of poultry has been an important subject of investigation. It will be noted that all of these projects have to do with food uses.

The only research disclosed by the survey on nonfood uses of poultry or poultry products other than eggs relates to use of the materials now largely wasted during poultry slaughter, dressing, freezing, or

storage. Many of the problems involved here relate to such activities as are found also in connection with meat packing, milling, or the processing of other agricultural materials. As in the other industries, the present major nonfood objective of most investigations has been the preparation of animal feeding stuffs. The fact that the raw material is already largely concentrated at central dressing plants would appear to be an important economic advantage for these developments.

Other nonfood research work in progress has the following objectives:

1. The utilization of packing-house trimmings such as legs, visceral fat, and heads. Most of this research has been limited to a determination of constituents that might be recovered and utilized.

2. The recovery of gelatin from waste leg tissues, with the object of making products suitable for surgical and other special uses.

3. The manufacture of food for pet dogs and cats from killing-plant offal. This has been attempted, but successful commercialization has been limited.

4. The recovery of therapeutic products from the endocrine glands of chicken heads. Much further work is needed on this project.

5. The manufacture of products from feathers. The available supply of approximately 20,000 tons of feathers annually indicates the economic advantage of further investigations. The making of insulating materials and special compounds, such as cystine or other sulphydryl compounds, is a possibility.

Eggs and egg products.

Eggs are used almost exclusively as food. Relatively little fundamental research has been done on eggs themselves; most such investigations relate to the production of larger numbers or better quality of eggs as a part of poultry-breeding and poultry-feeding studies. Most of the work that has been done on the eggs themselves relates to determination of quality or to the treatment of eggs to retard quality deterioration while in storage. These and other present researches are principally of the following types:

1. Treatment of shell eggs with oil, other chemicals, or gases to improve their storage life.

2. Search for improved methods of breaking, freezing, and drying whole eggs or yolks and whites separately.

3. Use of low-grade eggs—rots and incubator rejects—in the tanning industry. Such limited use as is made of eggs in this way is on an empiric basis rather than as a result of careful research.

4. Use of egg albumen, either dried or frozen, as a thermoplastic adhesive in cork-metal closures in bottle caps; as a clarifying agent in wines or other beverages; in the preparation of such chemical compounds as ammonium, iodine, or quinine albuminate, as sizing for paper; and as a reagent in dyeing, calico printing, and color photography. Little or no specific information is available as to actual research being done in the last connection.

5. Fundamental research undertaken by Federal, State, and public-health institutions looking toward the isolation of such biologic principles as lysozyme of egg white, an agent which digests certain types of micro-organisms. A second such principle has been prepared by the concentration of the "antitryptic" compound of egg white. This is an agent that inhibits the action of protein-splitting enzymes like trypsin.

Researches such as these only point the way toward the discovery and recovery of compounds as yet unknown which are locked within these complex biological systems. The value of such compounds in the field of applied medicine is only conjectural, and cooperative research between agencies properly qualified should be given careful consideration.

6. Fundamental studies directed toward the determination of the physical and chemical properties of egg albumen and correlation of these findings with the mechanical ability to whip.

7. Vaccine preparation from chick embryos through inoculation and incubation. Commercial production of such biologics from this source shows promising possibilities and deserves careful consideration.

8. The development of methods and equipment for judging the interior quality of shell eggs and correlating such observations with other physical measurements, such as height of the yolk, area of firm white, and size of the air cell. Much research has been done on this.

9. Improvement of methods for freezing liquid egg materials. Some consideration has been given to this, particularly with respect to biological control, which is an exceedingly important factor in the handling of such perishable material. Quick freezing at low temperatures following carbonation of the liquid material has been attempted. It is estimated that approximately 208 million pounds of liquid egg is frozen as whole egg or is separated and frozen as albumen and yolk. The frozen whole egg and the frozen yolk both find a ready market in the baking, confectionery, and mayonnaise industries, and the production of these commodities can be fairly well gauged to avoid a burdensome surplus. This is not true of the frozen egg albumen. Albumen does find uses, many of them nonfood, where neither of the other products could be used, but the actual amount so used is comparatively small. There is a large surplus of frozen albumen in storage, approximately 500,000 pounds annually.

10. Utilization of eggshells. The breaking of such a tremendous number of shell eggs leaves the manufacturer of frozen or dried egg materials with thousands of pounds of eggshells, of which little use is now made. To a limited extent these are employed as constituents of chicken feeds or fertilizers.

11. Production of dried egg products of uniform quality and color. This country uses considerable quantities of dried egg products, mostly as dried albumen or dried yolk, with a limited amount of dried whole egg. Some work has been attempted in this field, but here again the emphasis has been on food utilization rather than the development of other new industrial uses. Because of certain food-regulatory measures, manufacturers have studied manufacturing methods with an eye to producing uniform quality in dried egg products. Uniformity in color and also in moisture and fat content of dried yolk or of dried whole egg are important.

12. Thinning egg white preparatory to drying. Several patents have been granted for methods of thinning "thick" egg white prior to drying. Some of these have been mechanical, while others are based on the controlled use of certain acids. In one such method, which has been developed for free public use, the protein-splitting enzyme trypsin is added to the thick egg white. Without the addition of some such agent the time required for the thinning is from 5 to 7 days, and considerable foam collects, which in many cases is not recovered and represents a loss. When a thinning agent such as trypsin is employed,

the time required is reduced to about 40 hours, little or no foam is formed, and the dried product is of a good uniform quality.

13. Thinning foam on fermented egg white. Another application of enzyme activity has been developed on a pilot-plant scale. This is the use of pepsin for thinning the great quantities of foam from vats of fermented egg white and for drying the thinned product for technical uses.

SUGGESTED RESEARCH

Poultry.

Many recommendations have been made to the Department regarding further needed research on poultry and products of the poultry industry other than eggs, but the vast majority of such recommendations still deal with questions of food supply. Even those that have great promise of benefiting the industry in the field of freezing, other preservation, and preservation of quality in storage, are of this class. So little work has been done on any nonfood use other than feed as to make exploratory work of the most preliminary nature a necessary first stage for practically all other kinds of investigations. Those of the following suggestions which appear to have most practical promise are all of this exploratory character.

The major suggestions which have been made to the Department on nonfood investigations are:

1. Most important of the exploratory investigations will be the determination of the major constituents of present poultry wastes in order to determine by the most modern physical and chemical methods what quantities of possibly useful constituents are available for new manufacturing.

2. Biochemical investigations on glands and heads might well yield valuable biologic principles which would find new application in the field of applied medicine.

3. Feathers are rich in sulphydryl compounds and offer a possible source of these compounds for use as raw materials. These compounds are used in the prevention of darkening of cut fruit and medicinally.

4. There is also the possibility of recovering the small fibrils of feathers for spinning and weaving.

5. The considerable quantities of blood that may be collected at dressing plants offer a possible source of protein-rich compounds.

6. The hatchery waste of baby cockerels must be given consideration. Recovery of proteins or biologics from the thousands of day-old cockerels now killed and thrown away may possibly reveal a rich source of sex hormones, which might find use in the field of medicine.

Eggs and egg products.

Eggs consist essentially of three component parts: The albumen or egg white, approximately 60 percent of the egg; the yolk, approximately 30 percent; and the eggshell, which together with its membranes constitutes approximately 10 percent. Nature intended these complex biochemical systems to be the means of propagating the species rather than as food. When considered as sources of raw materials for industrial utilization, they offer a rich raw material for the recovery and separation of biologics, for which they may prove to be more valuable than for food.

1. Before plans for more scientific processing and more varied industrial utilization can be formulated for egg products, a more intimate knowledge of the composition of eggs is essential. Comprehensive and exhaustive studies of an analytical nature must be made as a basic scientific study, using the best skill and most modern research methods and equipment available. Such research is needed to complete our meager knowledge of basic composition. It will probably reveal the presence of many compounds valuable either for medicinal or other special industrial uses.

2. Egg yolk, because of its great diversity in composition, not duplicated elsewhere in nature, should be a valuable raw material rich in research possibilities, such as the recovery of lecitho-proteins.

3. The lipoidal or fat constituents of egg yolk are very complex in nature and should be made the subject of scrutinizing research on their physical and chemical properties. Because of the little-known chemical nature of egg yolks, they present an interesting and possibly fertile field for preparation of such substances as the sex hormones, growth-stimulating factors, and also some of the vitaminlike phosphoric acid compounds. Uses for such substances have barely been touched upon.

4. The oxidizing-reducing enzyme known to be present in egg yolks needs further fundamental research on the mechanics of its action. Until this information is available, color in either frozen or dried egg yolk will be hard to stabilize, and this lack of control may very readily be a serious obstacle to industrial use of the products.

5. The sugar content of the whites should be investigated. It in itself is of no particular value, but because of its apparent peculiar linkage to the protein, research on this biochemical structure would be of great value in gaining an understanding of the nature of changes that take place during extended storage. The results should be applicable to the approximately 500,000 pounds of frozen egg white that as an annual surplus is available for either industrial or food utilization.

6. A study of the physical and chemical changes taking place during the freezing and drying of eggs is necessary for improvement in methods of storage and quality production and needs collaborative research between biochemists and physicists.

7. Biochemical investigations to follow changes during storage are needed in order to maintain intelligent control of quality.

8. Biological control of processing is exceedingly important; this phase of the industry is sadly lacking in fundamental knowledge. Comparatively little basic information is available relative to the effects various processing methods have on the component parts of egg protein or the yolk constituents. This knowledge is necessary for the production of uniform products.

9. Process control needs attention if uniform qualities are to be maintained. Such a study will demand the attention of chemists, physicists, and engineers; it should include attention to such factors as humidity, moisture content, temperature, and atmospheric exposure. This type of control is just as important in the manufacture of raw products for the purpose of further industrial utilization as for food products.

10. Special sterols and growth-promoting factors from partially incubated fertile egg yolks are worthy of attention looking toward their separation and recovery. Biologics such as these may prove to be exceedingly valuable in the correction of abnormal conditions in human beings and animals.

11. The character of the protein of shell membranes should be investigated, as well as the mineral constituents of the eggshells. The isolation of valuable compounds is entirely possible and would convert a present nuisance waste into a profitable product.

12. Technological information is also needed in manufacturing and processing operations and in methods for the determination of quality of the manufactured products. These studies have been strongly urged.

MEAT AND MEAT PRODUCTS

PRODUCTION AND CONSUMPTION

The main area of meat production in this country corresponds to the region of surplus feed production. This includes the central grain belts, roughly the vast triangular territory of which Ohio, South Dakota, and Texas form the angles. Of a total yearly income to producers, averaging something over a billion dollars from hogs, a little under a billion from cattle, and some 150 to 200 million dollars from sheep, the largest sales and incomes are in Iowa, Nebraska, Illinois, Minnesota, Kansas, Missouri, Texas, South Dakota, Indiana, Wisconsin, and Ohio. This area is in general the region of surplus meat production as compared with the eastern area, which is the region of deficient meat production. The general direction of market movement of meat products, therefore, is from western feed lots and pastures to the large eastern cities.

Over the last 40 years the annual production of beef in this country has ranged from 6 to 7 billion pounds. The production of pork has ranged from about 6 to 9 billion pounds plus an additional 1½ to 2 billion pounds of lard. Production of veal has climbed from about half a billion to a billion pounds in recent years. Mutton, and more especially lamb, likewise have steadily increased from an output of about 500 million pounds to about 850 million pounds in the last few years.

Per capita consumption of beef in recent years has ranged from about 49 to 59 pounds; the per capita consumption of pork from 55 to 75 pounds; of lamb and mutton from 5 to 7 pounds; and of total meats from 116 to 148 pounds annually. The relation between production and consumption in recent years is shown in table 26:

TABLE 26.—*Total and per capita production and consumption of federally inspected meats, including lard, and United States population (average for 1929-33, and annually from 1934 to 1937)*

Year	Production			Total consumption of all meats, including lard	All meats, including lard		Population on July 1 ²
	Pork, including lard	Beef and veal ¹	Total meats, including lard ¹		Per capita production	Per capita consumption	
	Million pounds	Million pounds	Million pounds	Million pounds	Pounds	Pounds	Million
1929-33 (average).....	8, 077	4, 725	13, 379	12, 578	107. 99	101. 59	124
1934.....	7, 231	5, 602	13, 458	12, 794	106. 28	101. 23	127
1935.....	4, 406	5, 167	10, 274	10, 634	80. 57	83. 37	127
1936.....	6, 101	5, 970	12, 751	12, 164	99. 28	94. 72	128
1937.....	5, 301	5, 374	11, 359	11, 816	87. 88	91. 42	129

¹ Excludes meat for Government slaughter in 1934, 1935, and 1936.

² Bureau of Census.

EXPORT TRADE

Formerly, in the days of cheap feed, the United States was a large exporter of meat products, especially pork. The peak of meat exports was reached in 1918, when more than 2½ billion pounds (fresh meat basis) of meats were shipped abroad. From that peak year the exports of meat gradually dwindled to 164 million pounds in 1937.

Exports of pork and lard steadily declined from 1900 to 1914. The World War injected a temporary demand that increased the export of pork sharply. In 1920, however, foreign demand declined abruptly and continued its descent until 1937 when only 63 million pounds of pork were exported. European demand for lard held up somewhat better than that for pork for several years. But this trade too fell off sharply in 1935 and was still at low ebb in 1937, when only 137 million pounds of lard were exported.

The small export trade in 1935 and 1937 was partly due to the reduced supply of hogs resulting from the droughts of 1934 and 1936. Exports of pork and lard have recently increased appreciably. During the first 9 months of 1938, pork exports amounted to 69 million pounds and lard exports to 148 million pounds, as compared with 43 million pounds of pork and 77 million pounds of lard in the corresponding period in 1937.

The tremendous losses in the export trade in pork have played a very significant part in the corn situation. Since a large part of the corn crop is marketed in the form of hogs, the system of corn and hog production, which was geared to an export trade approaching a billion pounds of pork a year, has required far-reaching readjustments in recent years.

SURPLUSES

Tangible figures on surpluses are difficult to obtain as stocks of meat animals are at all times carried on the farms. As for the meat itself, the annual carry-over is revealed in the figures on cold-storage holdings. Cold-storage stocks of pork on March 1 of the years 1930 to 1934 averaged 735 million pounds. Since production of pork was sharply affected by the droughts and corn shortages of 1934 and 1936, the stock in cold storage on March 1, 1936, amounted to only 451 million pounds. The following year it rose to 776 million pounds, and on March 1 of 1938 it stood at 583 million pounds. In recent years, the cold-storage stocks of lard have ranged from 100 to 200 million pounds. Ordinarily less beef than pork is carried in storage. The stock of beef in storage on March 1, 1937, amounted to 167 million pounds, and on the same date in 1938 to 57 million pounds.

The movement of pork into storage is usually from early November to March; that of lard is usually from December to August. Most of the movement of these products out of storage occurs in the summer and fall. The total movement into storage is influenced considerably by the prospective supply of hogs for summer slaughter in relation to winter marketing. Prospects of a relatively small summer slaughter tend to encourage the accumulation of large storage holdings, whereas indications of a large summer slaughter tend to have the opposite effect.

PRESENT STATUS

The present meat situation is sharply affected by the feed shortages of 1934 and 1936, and stockmen are now trying to build up herds and reserves on the abundant feed crops of the last two seasons. The ample feed supply harvested this fall is expected to result in further expansion of livestock production in 1939. Total supplies of meats in 1939 will be larger than those for 1938, but they will still be somewhat below the average of the 5 years preceding the 1934 drought. Increase in meat supplies in the coming year will be practically confined to pork. The present tendency to withhold cows and heifer calves from the market in order to build up breeding herds will operate to curtail beef output somewhat in the next year or so.

Consumer demand for meat is expected to increase slightly during the coming year. Evidence indicates that the amount of money consumers spend for meat is gaged by their incomes in the given season. When industrial conditions are good and wages and income high the amount spent for meat is larger than in less prosperous times. This operates to raise the price of meat in prosperous years provided that the supply has not increased too greatly at the same time. This relationship between industrial conditions and meat prices is well established and bears significantly upon the broad problem of the meat market and potential surplus.

MEAT PRODUCTS AND BYPRODUCTS

Dressed beef, veal, pork, and lamb are the principal meat products. Articles such as lard, cattle hides, calfskins, wool and mohair, and sheep and lamb skins, as well as manufactured products such as sausage, oleo oil, and stearin, are often classed as byproducts, but because they have substantial aggregate sales values, these items may be properly designated as major products rather than as byproducts.

Byproducts naturally fall into two general classifications, those used as food and those which are inedible. Of the former the more important articles are tongue, brains, meat portions of the head, livers, kidneys, tails, sweetbreads, pigs' feet and tripe, and intestines used for sausage casings. Intestines are also used for inedible products, such as surgical ligatures and violin strings.

INEDIBLE BYPRODUCT UTILIZATION

The principal inedible byproducts (except wool, hides, and skins, which are discussed separately) and some of their important uses are as follows:

(1) Glands, such as the thyroid, parathyroid, pituitary, pineal, thymus, adrenal, gonads (sex glands), and pancreas, from which are derived a variety of important pharmaceuticals, including insulin, pepsin, pancreatin, thyroid extract, adrenalin, and many others. Due to the necessity of obtaining the glands quickly and in commercial quantities in order that their pharmaceutical properties may not deteriorate, only the larger meat packers are able to find a market for this class of product. Improvements in methods of preservation might make it possible for smaller packers to enter the field more extensively.

(2) Bones, hoofs, and horns, which are used principally for making fertilizers, feeds, glue, gelatin, bone byproducts such as combs and knife handles, bone black, oils, and soap greases.

(3) Hair, which is used principally for upholstery.

(4) Sinews, fats, and blood, which are used in the preparation of a variety of products, such as blood albumen, glue, gelatin, fertilizers, animal feeds, soap, glycerin, a variety of oils, and tallow.

Meat packers quite generally realize that it is usually more profitable for them to utilize as much of their product as possible for edible purposes. Therefore, only those byproducts which because of their nature or of health or sanitary restrictions cannot go into edible consumption are diverted into inedible channels under usual market conditions. Sometimes market values of products which, with a certain amount of labor, can be utilized as edible reach such a low level that a processor finds it more profitable to market the product as inedible. Thus, without a clear definition to distinguish between edible and inedible products or even between major products and byproducts, it is difficult to determine accurately relative values of major products, edible byproducts, and inedible waste. Relative values also necessarily change constantly as supply and demand for particular items change. However, it has been estimated that the relation between the value of major products and byproducts derived from the various species of meat animals slaughtered in packing houses is that shown in table 27.

TABLE 27.—*Relative proportion of major products and byproducts derived from meat animals*

Meat animals	Meat, lard, skins, or hides	Byproducts
	Percent	Percent
Hogs.....	96.6	3.4
Cattle.....	95.9	4.1
Calves.....	92.8	7.2
Sheep and lambs.....	95.9	4.1

The value of byproducts sold as edible probably exceeds that marketed as inedible. While the value of byproducts as compared with total value is small, owing to the number of animals slaughtered the aggregate realization is large. Table 28 shows the value of the various products of the meat-packing industry for 1935.

TABLE 28.—*Plant value of products of the meat-packing industry for 1935*¹

Product	Value	Portion of total value
	Million dollars	Percent
Edible:		
Meats.....	1,683	85
Lard.....	129	7
Shortenings and oils.....	30	1
Total.....	1,842	93
Inedible:		
Hides and skins.....	81	4
Wool and hair.....	17	1
Tallow and grease.....	23	1
Animal feeds.....	10	1
Other inedible products.....	6	
Total.....	137	7
Total.....	1,979	100

¹ Calculations from data of the Biennial Census of Manufactures, 1935.

PRESENT RESEARCH

Current research in the United States on animal products, excepting hides, skins, and wool, deals both with food uses and with industrial utilization. To a large extent the former type of work is being conducted by State agricultural experiment stations and the United States Department of Agriculture, and the latter type largely by industry. Research on food uses may be classified under three main heads—animal production, meat processing, meat and meat products. Research relating to industrial utilization of meat-animal products has been subdivided into fundamental research and industrial utilization of byproducts. Specific problems of research now in progress are:

Animal production.

1. Breeding as a factor influencing economy of production and the quantity and quality of edible products of meat animals. Various breeds, strains, crosses, and types of hogs, sheep, and cattle are being studied, with the principal objective of developing improved strains that will produce meat of the most desired quality at low cost. Numerous specific problems are included in this program, for example, the problems relating to economy and rapidity of gains in live weight, and to fatness, proportions of parts or cuts, tenderness, and color of lean tissue.

2. Nutritional studies: Nutrition is probably receiving major attention among the several animal production factors under consideration. Certain carcass and meat characteristics of cattle, hogs, and lambs command primary interest and attention; therefore, the effect of various feeds, such as grass, roughage, full-grain and limited-grain rations, grain with roughage, and soybeans, on the production of desirable meat qualities are being investigated. Dressing percentage, physical and chemical composition, and color of the lean and fat tissues are among the important factors considered in measuring the effects of differences in feeding. In addition, the influence of different feed levels on fatness and fat distribution, proportions of the different parts of the carcass, ratio of edible meat to bone, softness of pork, etc., is also being investigated. On the whole, research on lambs is receiving much less attention than that on cattle and hogs. Considering the much lower production and consumption of lamb meat in the United States this would appear to be logical.

3. Investigations on sex, grade, and methods of baby beef production: Significance of sex in cattle in relation to quality of the edible product and to other factors is being studied. Research on grades has for its principal objective the characterization of the recognized grades in specific terms, such as physical and chemical composition, proportions of primary cuts, color, marbling, and tenderness. In addition, some of this type of research involves livestock management factors as basic variables distinct from breeding, feeding, and other factors.

Processing factors.

4. Storage studies of fresh meat at above freezing temperatures: The relation of temperature, humidity, and air circulation to control of spoilage and ripening is being considered. The major objective is to determine the most desirable combination of temperature, humidity, and rate of air circulation for each kind and grade of meat. Investigations are in progress on keeping quality, or rate of ripening, of

fresh beef produced on different rations, as well as the comparative behavior at a temperature of about 35° F. of beef of equal fatness produced on grass alone and on a standard ration of grain with hay.

5. Freezing and freezer storage investigations: Recent years have seen a remarkable development of interest in low-temperature preservation of meat and other foods in the United States. The principal objective is to determine the effects of temperatures of freezing and of storage of frozen foods on such variables as tenderness, juiciness, dehydration, flavor (including rancidity), and other factors.

6. Curing studies: Curing studies, made especially on pork, involve such basic variables as temperature, time, curing mixture, and method of application in relation to preservation and quality of the product. Investigations on aging of cured meats involve the influence of temperature, time, antioxidants, and degree of protection from or exposure to air on the quality of the cured, stored meat. The "rapid aging" of cured hams at high-storage temperatures is also receiving attention.

7. Canning and cooking studies: These studies are directed toward the development of methods for home use that will definitely insure preservation, and, at the same time, result in a high-quality product for the table. Studies are being made of the effects of different methods and different temperatures of cooking and of different internal temperatures of meat on the losses of total and of specific nutrients and on palatability factors. Methods of cooking frozen meats and soft pork are under investigation.

Meat and meat products.

8. Studies on palatability factors such as tenderness, including practical and fundamental work on tendering; flavor, intrinsic and developed; juiciness, with reference to quantity and quality of juice; and finish or fatness in relation to palatability.

9. Nutritional studies on disease preventive substances and accessory food factors, including vitamins, in meat.

10. Studies on physical and chemical characteristics, including color, composition, firmness, and water-holding capacity. Work on quality of lard is included.

11. Studies on meat and meat-juice extracts, including development of new and improved extracts and concentrates for pharmaceutical purposes.

12. Methods for measuring flavor (both intrinsic and developed), quality and quantity of juice, fat content, dressed carcasses, and their relation to quantity and quality of meat. Also under investigation are methods for testing and identifying mixtures of beef oils and lard.

Fundamental studies on animal constituents.

13. Studies on the proteins of bone, hair, blood, glands, and organs, including the separation, identification, and characterization of the individual proteins.

14. Studies on fat, dealing with rancidity, molecular distillation, and decomposition into simpler units as, for example, separation of individual glycerides and isolation of fatty acids for use in synthetic processes.

15. Enzyme and hormone investigations, including isolation, purification, identification, characterization, standardization, etc.

Nonfood utilization of byproducts.

16. Studies on fats: These studies are designed to develop new and enlarged uses for lard, oleic acid, stearine, and related products. Other work relates to grease compounding and to testing substitutes for glycerine in softening of fiber.

17. Studies on bones, hoofs, and horns: This work is directed toward the production of gelatin, glue, and adhesives of higher quality and also toward the development of uses for bone other than for the manufacture of gelatin and glue.

18. Studies on gelatin: Gelatin is being studied with a view to its use in the manufacture of photographic film and paper, in adhesives, in sizing, and in combination with artificial silk for the production of a substitute for sheep gut in tennis rackets. Investigations are under way on the development of new glues and adhesives of special properties and for special applications, such as the binding agent in rubberized goods.

19. Studies on glands and organs for the production of pharmaceuticals. Efforts are being concentrated on active principles or hormones, irradiated and vitamin-rich concentrates, and enzyme preparations. Other work relates to the production of enzymatic leather bates from the entire pancreatic gland.

20. Investigations on blood with the object of converting it to an adhesive suitable for veneer and plywoods.

21. Studies on hair for the production of amino acids or related products for use in fine grain developers for miniature photography.

22. Investigations on tendons directed toward the development of a product resembling paper or parchment for drum heads, violin strings, sutures, etc.

23. Studies on wastes, such as economical recovery of protein from packing-house waste water and the development of new fertilizer materials.

SUGGESTED RESEARCH

Suggestions for research vary widely. Both food uses and nonfood uses are included, and in many instances the suggestions for study relate to problems on which research is now in progress. Hides, skins, and wool have been considered elsewhere. The problems suggested have been classified as follows:

Animal production.

1. Feeding effects on the keeping quality of fat and its quality for use in food preparation. The consistency and chemical composition of fat, particularly hog fat, are affected greatly by the type of ration fed. Differences in fat are reflected in the lard, and the relative qualities of the various lards should be determined.

Animal processing.

2. Development of strains of hogs yielding a lower ratio of fat to other products, thereby reducing the present surplus of lard.

3. Frozen pack and refrigeration studies to improve the quality of meat available in small markets, to extend consumption of meat, and to avoid losses and waste in long shipments of fat animals.

4. Freezing studies for the preservation of ready prepared, cooked foods.

5. Development from agricultural materials of a new and improved "smoke" for meat and meat products. This new product or method should impart improved quality and flavor to the meat and should possess rapid penetration and high antioxidant properties.

6. Development of more effective animal and plant antioxidants for use in the preservation of fat and oil products.

Meat products.

7. Nutritional studies on meat and meat products such as meat extracts.

8. Interpretation of meat grades to show the relative palatability, economy, and nutritive value of various cuts according to grade.

9. Studies on enzyme action in meat and the effects of such action under various storage conditions.

10. Lard studies designed to improve color, plasticity, stability, nutritive value, rendering methods, etc., thereby increasing the value as well as desirability and use of this fat as a food.

Fundamental research on animal constituents.

11. Studies on isolation and identification of the constituents in the unsaponifiable fraction of animal fats and oils.

12. Investigation on the isolation of new and improved pharmaceuticals, such as thromboplastin, adrenalin, and sex hormones, from glands and organs. More rapid and less expensive methods of vitamin and drug assay or analysis for use in control work should receive attention. Brains should be studied with respect to use in the economical production of cholesterol, lecithin, and related compounds.

13. Protein studies, including isolation and hydrolysis to amino acids. (For general discussion of this subject see section on Proteins in report on Dairy Products.)

Nonfood utilization.

14. Studies on development of new and extended uses for lard, hoofs, and horns.

15. Utilization studies on bones for the production of bone black and bone china or high-quality porcelain. Separation of proteins from green bones should be investigated with the objective of producing glue.

16. Investigations on blood (1) for the production of albumen which may compete more effectively with imported albumen; (2) as a source of raw materials for the manufacture of plastics; and (3) for the preparation of the individual amino acids useful for commercial and therapeutic purposes.

17. Waste studies: This problem should include the economical recovery of constituents, especially protein and fat, from packing-house water, and the advantageous utilization of the recovered constituents.

18. Investigations on the production of new and improved adhesives from animal byproducts.

19. Studies on fats and oils for the production of lubricants for special purposes.

20. Investigations on gelatin for the purpose of adapting it to the manufacture of artificial straw.

ANIMAL FIBERS FOR SPINNING

The principal animal fibers used in the United States for the manufacture of textile fabrics are wool, mohair, and silk. A number of others, not covered in this Survey, are used to a less extent, the most important being alpaca, vicuna, llama, cashmere, and camel's hair. The essential chemical difference between animal and vegetable fibers is that the former are composed of protein, whereas the latter are composed very largely of cellulose. The protein of animal fibers makes them take certain types of dyes which cannot be used on vegetable fibers, makes them less water-absorbent than vegetable fibers, imparts resistance to deterioration by dilute acids, and gives them a considerable degree of fire resistance. Animal fibers also possess physical properties which make them superior to vegetable fibers for the manufacture of certain kinds of textile fabrics.

Wool and mohair are the only animal fibers produced commercially in the United States for spinning. Several attempts have been made to develop a silk-producing industry in this country, but these have demonstrated that the establishment of this industry would be impractical because of the great amount of hand labor required. Recently, however, attention has been directed toward the possibility of replacing some of the hand labor with machines.

WOOL

The wool-growing industry has undergone set-backs from time to time during the last 25 years, but it has not been handicapped by surplus production as that term is ordinarily understood. For many years the textile mills of this country have used more wool than is produced domestically and have had to import considerable quantities.

It is estimated that there are in the United States about 472,000 wool producers and about 46 million sheep. In recent years the annual production of shorn wool has averaged about 350 million pounds. In addition, there is an annual production of 55 to 65 million pounds of pulled wool, which is obtained from the skins of slaughtered sheep.

The wool-growing industry of this country has shifted westward until now two-thirds of the shorn wool is produced in the Rocky Mountain and Pacific Coast States. Texas has the largest production of any State, although relatively little wool is produced in the other Southern States.

In the East, sheep are usually raised in small farm flocks of a dozen to possibly a hundred head of shearing age. Such flocks are common as adjuncts to general farming, serving to utilize hill pasture and rough forage. In western range States, often called the "territory States" in the language of the wool trade, sheep in flocks of 1,000 to 2,000 graze over open range country throughout the year. Sheep raisers in the range States clip from about 5,000 up to as much as 400,000 or 500,000 pounds of wool a year. Usually the clip runs from 25,000 to 100,000 pounds.

Generally speaking, the Rocky Mountain States produce the fine-fiber wools characteristic of the Rambouillet and Marino breeds, which are present to some degree in most of the flocks of that region. Farther east the Down breed predominates and the wools are coarser, except in southern Ohio and adjoining parts of Pennsylvania and West Virginia, where fine wools are produced.

Only about 60 to 70 percent of the wool consumed in the United States is produced here. Some 30 to 40 percent must be imported. The present duty on foreign wool is 34 cents per pound on the basis of the yield of scoured wool. However, because the United States produces little or no wool suitable for carpet manufacture, wools for this purpose are admitted duty-free. Such wools must be below a certain grade, defined in the Tariff Act. The chief ports of entry for foreign wool are Boston, New York, Philadelphia, and San Francisco.

Wool production, consumption, and imports into this country during the last 5 years are shown in table 29.

TABLE 29.—*Wool production, consumption, and imports, 1933-37*

[In millions of pounds]

Year	Total production	Mill consumption, apparel class, shorn-wool basis	Net imports	
			Combing and clothing	Carpet wool
1933.....	438	572	59	114
1934.....	431	381	29	79
1935.....	431	713	42	158
1936.....	426	618	111	143
1937.....	433	524	150	172

The 1938 wool crop was estimated at about 369 million pounds, slightly more than the average. The increase in 1938 over 1937 was caused by an increase in the number of sheep shorn.

Available supplies of apparel-class wool in the United States in the fall of 1938 were considerably larger than in the preceding year or two. As a result of the large imports and reduced mill consumption in 1937, the carry-over of old wool into the 1938 marketing season was much larger than the carry-over from the previous year. Increases in mill consumption if not accompanied by an increase in imports will probably result in smaller stocks of wool on April 1, 1939, than were available on April 1, 1938.

The world output of wool in 1937, excluding that of Russia and China, totaled 3,487,000,000 pounds, the largest production in recent years. Preliminary estimates indicated that world production in 1938 would be slightly smaller. Wool production in Australia in 1938, as compared with that in 1937, was expected to show a reduction of about 6 percent.

The gross farm income received by domestic wool producers in 1937 amounted to 117 million dollars. In 1936 it totaled 97 million dollars.

The prewar (1909-14) average price for wool received by producers throughout the United States was 18.3 cents per pound. In recent years the weighted average price to producers, covering the entire year in each case, has ranged from 8.7 cents a pound in 1932 to 32 cents a pound in 1937. During most of that time the season price averaged from 21 to 25 cents a pound.

The Government loan program for wool producers provided an important stabilizing influence on domestic prices after April 1938. A total of some 93 million pounds of wool had been appraised for loans during the succeeding 6 months. The loans averaged about 17.66 cents per pound of wool in the grease at warehouses.

It seems probable that the prospective improvement in mill consumption in 1939 will have a supporting influence on domestic prices. On the other hand, the spread between the prices of domestic and foreign wool has increased in recent months and is now slightly more than the tariff. Consequently, a substantial rise in the price of wool in this country will depend on a rise in foreign prices.

MOHAIR

Mohair is obtained from Angora goats. The Angora-goat industry in the United States is confined mainly to the Southwest. Large numbers of these animals are raised in the Edwards Plateau area in the southwestern part of Texas, the average number per farm being somewhat over 300.

In the last 10 years the average number of Angora goats in the country has been somewhat over 4 million, and the annual production of mohair slightly over 16 million pounds. Texas alone produces 13 to 14 million pounds of mohair each year.

Mohair brought producers an income of about \$8,500,000 in 1936 and nearly \$9,000,000 in 1937.

Imports of mohair have been small in recent years, exceeding 1 million pounds in only 2 years since 1929. From 1931 through 1934 production in this country apparently exceeded domestic consumption, and there was considerable accumulation of stocks, but this was reduced in 1935-36. It appears, however, that in the past 5 years mohair production has been sufficient for domestic needs, and a marked increase in mohair production would probably result in lower prices, and perhaps reduce, if not destroy, the effectiveness of the present tariff on mohair.

Mohair is used especially for the manufacture of plush fabrics for automobiles and furniture.

PRESENT RESEARCH

A summary of the findings of the Survey on present and suggested research on the chemical composition of animal fibers is included in the section on the fundamental investigations of proteins. Other lines of research are:

Animal husbandry and nutrition.

1. The effects of hybridization, selection, type conformation, breed, age, feed, and pasturage on the rate of growth of the sheep and the amount and quality of wool produced.

2. Seasonal and climatic variations in wool production.

3. The effects of the aforementioned factors on manufactured products.

4. Relation of the chemical composition of the diet and the properties of the fiber (especially silicon content) to the quality of the wool. In these studies the properties of the fiber investigated for the purpose of measuring quality are crimp, density, diameter, length, elasticity, and uniformity.

5. Investigations on the causes of medullated wool fiber, black fiber, and other abnormal fibers in the fleece.

Sorting, scouring, and carbonizing.

6. Improvement on the present method of branding fleece.
7. Improvement in cleaning fleece before shipment.
8. Practicability of grading in the producing sections.
9. Comparative studies on clip shrinkage.
10. Causes for variation in shrinkage, and the relation of the shrinkage of various parts of the fleece to the shrinkage of the entire fleece.
11. Investigation of spontaneous combustion in wool (due to wool grease).
12. Study of the three methods commonly used for separation of the wool grease, namely, soap and alkali scouring, solvent scouring, and freezing.
13. Study of the carbonizing process—removal of cellulose and other vegetable matter by means of sulphuric acid, hydrochloric acid, or aluminum chloride.
14. Optimum temperature for drying carbonized wool.

Manufacturing processes.

Most of the textile processes for wool are being studied, with a view to improving old methods and devising new ones.

15. Development of new types of fabric, improvement of the fulling process, of the bleaching, dyeing, and printing processes, and of the finishing processes in general.
16. Study of water-soluble dyes for home dyeing, and the action of dyes and detergents upon the fiber.
17. Studies on the absorption of water, oils, and alkalies.
18. Effect of cell and fiber structure on elasticity and on dye absorption.
19. Theory of fulling and the effect of acidity on fulling.
20. Special finishes to protect against moths, deterioration, and rancidity.
21. Prevention of shrinkage by treatment with halogen derivatives.
22. Effect of heat sterilization on the properties of the fabric.
23. Prevention of pile crushing of plushes and velvets and the production of noncreasable fabrics.
24. Increasing the wear of felt by chemical treatment such as tanning.
25. Studies on the improvement of animal fibers by the formaldehyde treatment.

New and extended uses.

26. Special felts for use in paper mills.
27. Increased use of wool in children's playsuits, blankets, and upholstery.
28. Effect of the proportion and quality of wool in wool-rayon and wool-cotton blankets upon the wear and warmth of the blankets.
29. The recovery and utilization of byproducts, such as the potassium salts and lanolin in the scouring wastes.
30. Recovery and reuse of wool in old fabrics.

Usage defects.

31. Deterioration of wool and wool dyes caused by visible and ultraviolet light.
32. Effects of temperature, humidity, and oxygen concentration on this deterioration.

33. Deterioration caused by heat, acids, alkalies, chlorine, bacteria, molds, and enzymes.

Testing.

34. Work on standards for mohair, wool, and wool tops, especially as regards length of staple and grade.

35. Evaluation of wools for special uses, such as carpets.

36. Detection of damaged wool.

37. Use of the microscope in testing methods and in the study of cell structure.

38. Determination of mohair and wool by scale size and diameter and identification of fibers by the aid of fluorescence.

39. Specific investigations on drying, regain of moisture, porosity, resistance to abrasion, dielectric strength, tensile properties (the effect of acidity has been specifically investigated), and electrokinetic properties.

Economic research.

40. An economic study of the fine-wool industry in southwestern Pennsylvania. This includes forecasting prices in the wool market, the effect of quality and physical properties of the fiber on the cost of products, and other subjects of economic importance.

Fundamental research.

41. Investigations to determine microscopically the finest structural details of wool, with special reference to origin and development.

SUGGESTED RESEARCH

Suggestions received during the Survey for research on wool and mohair may be summarized as follows:

Animal husbandry and nutrition.

1. The improvement of wool by improved animal husbandry.

2. Investigations on the kind of wool and mohair best adapted to specific purposes.

Sorting, scouring, and carbonizing.

The incomplete removal of materials used in branding fleece is very costly to the wool industry. The following lines of research on this problem have been suggested:

3. Investigations on branding unimportant parts of the fleece.

4. Development of improved methods of branding to prevent the retention of tar in the fleece.

5. Studies designed to find branding material more easily washed out with soda ash or soap.

6. Studies on better and cheaper tar removers.

Manufacturing processes.

7. Studies on improved sizes and finishes for woollen fabrics.

8. Development of a method of increasing resistance to abrasion.

9. Investigations on the lubrication of wool by different oils.

New and extended uses

10. Investigations on new fabrics and improved processes for felting.

11. Investigation on the recovery of potassium salts and lanolin and extension of uses for these materials.

Testing.

12. Development of standard specifications in collaboration with the American Society for Testing Materials.

13. Methods for the determination of shrinkage, resilience, and the kinds and amounts of different fibers in mixed cloth.

Fundamental studies.

14. Research on the structure of wool and other animal fibers, parallel to similar studies on cotton and other plant fibers.

SILK

Silk is one of the best of the natural fibers. Silk yarns and thread are manufactured from fibers produced by the silkworm during the spinning of the cocoon. The fiber is obtained by reeling it from the cocoon.

Commercial silk is produced mainly in Japan and China. Small quantities are produced in Italy, France, and India. In the United States silk is produced only for experimental purposes. Many attempts have been made to produce silk commercially in this country, but they have never been successful, because of the tremendous amount of hand labor required not only in raising the worms but also in reeling or unwinding the silk from the cocoons. The development of regenerated silk has stimulated interest in the possibility of establishing a silk-producing industry in this country, since the manufacture of this type of silk does not require expensive hand labor. Regenerated silk is produced by dissolving waste silk or perforated cocoons (those from which the adult moth has emerged), and forming the fibers by a process similar to that used in the manufacture of rayon. Spun silk (silk cut and spun in a manner similar to that used in spinning rayon staple fiber) may be made from whole as well as perforated cocoons.

The value of raw silk imports into this country has fallen tremendously during the last few years (\$421,393,000 in 1926-27 to \$87,437,000 in 1937-38) owing largely to the competition of rayon. No fiber, however, has been produced on a commercial scale that duplicates the desirable characteristics of silk, particularly its elasticity. Synthetic fibers are being developed with this aim in view.

PRESENT RESEARCH

Investigations are being carried on in several parts of the country on the raising of silkworms for the production of silk. These projects have three distinct objectives, namely, the production of ordinary continuous filament silk, the production of regenerated silk, and the production of cut fiber for spun silk. Work under way includes:

1. Agronomic research on growing different varieties of mulberry trees for feeding silkworms and the effects of the various kinds of leaves on the type of silk produced.

2. Study of cost factors in producing cocoons. The preliminary estimate is about 10 cents a pound.

3. Mechanical research with the following objectives: (a) Mechanization of the collection of mulberry leaves; (b) mechanical feeding of silkworms; (c) automatic control of temperature, humidity, and quantity of air supplied to the silkworm, including refrigeration storage, which is claimed to increase the number of "crops" in a given period; and (d) mechanical reeling of silk from the cocoon.

4. Studies to determine optimum conditions for the production of regenerated silk, including both chemical and mechanical studies.
5. Fundamental studies of the protein constituents of silk.

SUGGESTED RESEARCH

Specific studies include:

1. Investigations on the habits of the different varieties of silkworms to determine optimum conditions for feeding, mating, and handling, and means for protecting them from diseases.
2. Hatching and feeding experiments in buildings in close proximity to mulberry trees.
3. Agronomic research on the improvement and culture of different varieties of mulberry trees.
4. Study of the cost of the various factors in raising silkworms, particularly the cost of the mechanical gathering of mulberry leaves.
5. Studies to determine optimum conditions for storage of eggs.
6. Investigations on the complete mechanization of the production of silk from the cocoon.
7. Study of chemical and mechanical problems incidental to the production of regenerated silk.
8. Investigations on the properties, durability, and merit of silk fabrics and sewing thread in comparison with substitutes for silk.

HIDES AND SKINS

Hides and skins are among the highest-price-per-pound raw materials that agriculture produces. For the best flayed and cured hides and skins of cattle and calves the tanner often pays as much as or more per pound than the butcher pays for the dressed carcasses of these animals. Yet, because they are byproducts of another industry and frequently are marketed by methods that fail to discriminate in price according to quality, and thus do not provide an incentive for improving quality, hides and skins are all too often treated with the utmost indifference and with little regard for what should be done to realize their maximum potential value.

It is generally considered that for cattle an average of about 7 percent of the live weight and about 11 percent of the value of the live animal is in the hide. In the case of calves, the skin may equal as much as 20 percent of the value on the hoof. Obviously, the raiser of livestock has, therefore, a substantial proportion of his produce and source of income in the form of hides and skins. Just as animals cannot be raised without hides or skins, neither can leather be made without them. The agriculturist, therefore, is supplying essential raw materials for a basic industry producing an everyday necessity.

The importance of hides and skins is shown by the fact that annually in this country about 120 million of them, worth nearly 200 million dollars, are tanned into leather having a normal factory valuation of around 450 million dollars. This leather is converted into shoes, belting, harness, and other goods for which the people spend yearly close to 2 billion dollars. Toward meeting the requirements of the leather industry domestic agriculture supplies some 40 million hides and skins, worth well over 100 million dollars. It is necessary, however, to draw upon foreign countries for some 75 to 80 million hides and skins, worth about 75 million dollars. Theoretically, at least,

there is thus still available to domestic agriculture a potential market of tremendous magnitude.

In this country animals are not raised solely for producing leather-making hides and skins. The livestock population is governed primarily by other demands, as for meat, milk, and wool. By improving the quality of hides and skins and preparing them for market in the best possible state of preservation, domestic agriculture may participate to a larger extent in supplying raw materials to the leather industry. Improvement in the inherent properties of domestic hides and skins, as through breeding and special feeding, obviously would place these materials in a stronger competitive position. Elimination of the spoilage and waste of domestic hides and skins would mean more hide substance and better raw material for sale and greatly increased returns. Estimates of the annual monetary loss due to spoilage and waste of hides and skins from improper handling, faulty take-off, and poor cure have ranged from 10 to 20 million dollars. This loss is additional to that from damages of ante mortem origin, resulting from the attack of insects or infestation by parasites, the reduction or elimination of which damages would also greatly increase the aggregate returns for hides and skins.

Looking at the picture, therefore, in its broadest aspect it is evident that for the benefit of agriculture, the leather industry, and the Nation, hides and skins should be raised to the level of essential, valuable, staple, major projects and, as such, should receive concerted attention and efforts directed toward their increased production, improvement in quality, proper preservation, correct marketing, and most complete and efficient utilization.

PRESENT RESEARCH

The Federal and State Departments of Agriculture and agricultural experiment stations are engaged continuously in work on combating and eradicating insects, parasites, and diseases that attack livestock and result usually in serious damages to hides and skins. However, work of this character is not considered within the scope of this survey. Aside from this, only extremely limited attention is being given directly to the maximum development of the most desired inherent leather-making properties of hides and skins while still on the animal. In the aggregate, a tremendous amount of research and experimental work is being done on the improvement of livestock and the production of better meat, milk, and wool. Hides and skins from animals of known history are thus available from time to time at several State and Federal experiment stations. Quantitative studies, however, of the effect of such life factors as breed, sex, age, nutrition, and environment of animals upon the inherent qualities, and hence the intrinsic value, of their hides and skins have been almost completely neglected.

The problems relating to preservation and storage of hides and skins to reduce spoilage after removal from the carcass and until put to soak by the tanner are receiving attention, which, however, is definitely inadequate in view of the economic losses that result from improper practices.

The most important and valuable utilization of hides and skins is, of course, their conversion into leather. Consequently, the work of the tannery laboratories is devoted primarily, and in many cases

exclusively, to the chemical control of the numerous processes involved in tanning, the more critical examination and testing of supplies, the trial of new products and proposed improvements in processing, the formulating of oils, dyes, finishes, and other products according to plant and customer requirements, and the analysis and physical testing of leather. This work is supplemented to a limited extent by applied and fundamental research by the laboratories of the leather and allied industries, a few of the universities, and the scientific bureaus of the Federal Government. Such research is being conducted along the following lines:

Preservation and storage.

1. Brining experiments and application of results on a limited commercial scale.
2. The pickling of skins.
3. The cold storing of hides and skins.
4. The possibilities of better curing through the addition to salt of chemicals highly effective in preventing growth of micro-organisms.
5. Fundamental studies covering salt-tolerant bacteria and molds, causes and prevention of so-called salt stains, and bacterial hydrolysis of the proteins of which hides and skins are composed.
6. The seeking of chemical, physical, and biological criteria by which the state of preservation or, conversely, the spoilage of cured hides and skins can be measured and used in buying and selling these raw materials.

Utilization.

7. Modification of processes to reduce the time of tanning heavy vegetable-tanned leathers to several weeks instead of many months, without sacrifice of yields, quality, and character of leather. This problem is undoubtedly receiving the most attention.
8. Elucidation of the chemistry of vegetable, chrome, alum, formaldehyde, oil, and quinone tannages, and of the fore-tanning processes of soaking, unhairing, bating, liming, and pickling.
9. Fundamental studies on the fermentation of vegetable tanning materials and the role of fermentation in tanning and on the chemical constitution and structure of collagen, keratin, elastin, and other proteins and amino acids of which hides and skins are composed.
10. Development of enzymes of animal and vegetable origin for unhairing and bating hides and skins.
11. Comparative merits of animal, vegetable, marine, and mineral oils for use in oiling and fat-liquoring leather.
12. Development of improved formulas for coloring and dyeing leather.
13. Development and application of protein, oil, lacquer, resin, soap, and wax finishes for leather.
14. Development of a truly white tannage that will yield leather of a superior quality, equal in its characteristics and properties to chrome- and vegetable-tanned leathers.
15. The chemistry of leather deterioration in polluted atmospheres.
16. Development of either protected leathers or of tannages that produce leathers inherently resistant to acid decay and atmospheric corrosion.
17. Study of chemical and particularly physical means whereby leathers and leather goods can be more significantly appraised and their serviceability forecast to some degree.

18. New uses for leather: While recognized as having potential possibilities of economic significance to the leather industry and to agriculture, this subject is getting only scant and intermittent consideration.

19. The disposal of tannery wastes: This problem is a serious one for the leather industry and is daily becoming more acute and urgent because of the increasing importance of preventing stream pollution. This objective, coupled with the pressing need for plant operation at the highest possible degree of economy, is directing more active attention to valuable new products that might be recovered or made from tannery wastes and byproducts, such as used liquors, sludges, fleshings, hide trimmings, hair, and scrap leather.

SUGGESTED RESEARCH

An enumeration of suggested research in the more important fields of work on hides and skins follows:

Agricultural research.

1. The correlation, through fundamental research, of the influence of breed, feed, sex, age, and environment of animals upon the chemical composition and physical properties of their hides and skins.

2. A more intensive study of the influence of external parasites, such as ox warbles, mange mites, lice, and ticks, on hides and skins, with a view to developing remedial measures more effective than those now available.

3. A study of the feasibility of establishing in the United States an enlarged goat-raising industry, primarily to help meet its requirements of skins for making leather.

Preservation and storage.

4. The development of practical methods of curing that will insure the better preservation of hides and skins.

5. The establishment of methods and criteria for measuring the state of preservation of cured hides and skins.

6. The scientific elucidation of the causes of salt stains in hides and skins and the development of methods for their prevention.

7. The determination of the proper temperature, humidity, and rate of air flow, whereby meats, hides, and skins may be most rapidly dried without trapping moisture in the interior and with the least amount of protein denaturation.

Utilization.

8. An organized study of the most efficient recovery and most profitable utilization of tannery wastes, including used liquors, sludges, fleshings, hide trimmings, hair, and waste leather.

9. The development of rapid methods for making vegetable-tanned heavy leathers without sacrifice of yard yields, character, and serviceability of the leather, and with economical utilization of tanning materials.

10. The seeking, through fundamental research, of entirely new methods and agents for tanning hides and skins.

11. The study of oils, particularly of vegetable and domestic origin, for their more extended use in the tanning, oiling, and finishing of leathers.

12. The development of sterile processes for the vegetable tanning of leather to eliminate loss of tanning and dependence upon natural fermentation for the production of acidity.

13. The development of a combination chrome-vegetable tannage for sole leather to yield a product equal to straight vegetable tanned leather in plumpness, and ability to be channeled and to hold a satisfactory finished edge.

14. The development of a tannage producing an inherently white leather equal in character to vegetable- or chrome-tanned leather.

15. The study of the development of enzymes of vegetable origin for use in unhairing and bating hides and skins.

16. The study of a wider application of soybean proteins in the filling and finishing of leather.

17. The development of leathers for upholstery, belting, bookbinding, cases, bags, and straps that are inherently resistant to acid rot.

18. The development of physical, mechanical, and accelerated aging tests for appraising the quality of leathers and leather goods and for forecasting their serviceability.

19. The study of the effect upon human health of the wearing of leathers of different character and tannages.

20. An organized study of the requirements of the Army and Navy for leather-making raw materials and leather and of the most effective manner in which these requirements and those of the civilian population can be met in times of emergency.

FUR ANIMALS

In almost every civilization furs have been among the most valued articles of commerce. This was true among the Chinese 3,500 years ago, and later among the Greeks and the Romans. In medieval Europe fur was a luxury much sought after—and incidentally, men made greater use of it for clothing than did women. But it was not until after the discovery of North America that the world fur trade really got into its stride. That it early became an enormously profitable business on this continent is attested by the fact that an Indian trapper could often be induced to part with his winter's catch, worth hundreds of dollars, for a blanket or two and a bottle of rum—and perhaps not very good rum.

With pelts of fur-bearing animals readily obtained and profits large, no attention whatever was paid to the question of the possible exhaustion of the source of this wealth. The more furs there were on the market, the more popular furs became. The luxury of the rich became the necessity of the moderately well-to-do. The trap lines were run not less but more intensively, to the profit of many persons, including the professional trapper, the landowner, the farmer who could turn a few extra dollars without much trouble, and a large army of wholesalers, factory owners, retailers, and their employees.

Naturally a depletion of fur resources resulted. This cannot be attributed, however, entirely to overeagerness in trapping. The disappearance of the wilderness, the natural habitat of the fur animals, was a major factor. Nevertheless, even today the trappers and fur farmers of the United States receive 60 million dollars a year for the raw furs they bring to market. The annual retail turn-over is several times that amount; in 1929, the peak year, it reached half a billion

dollars. The United States is, in fact, the largest fur-consuming market in the world.

Today, instead of being the world's chief source of fur, the United States does not produce enough to meet more than a third of its own demand, and the demand is increasing rather than decreasing. To meet it, trappers still take fur animals from the wild with the same extravagant disregard of maintaining or increasing whatever supply is left. Our natural fur resources will unquestionably be completely exhausted unless measures are taken to strike a proper balance between supply and demand.

In this connection there is much need for greater knowledge regarding production. It is not known, for example, whether we are producing 10 million muskrats a year and trapping 13 million, or producing 5 million and trapping 25 million. We can be pretty sure that we are trapping more than we are producing; but it is important to find out how many more. In almost every State furs are a source of income for some of its citizens. The methods of handling these resources are almost entirely haphazard; few State game and conservation commissions have given sufficient serious thought to the matter. In most States there is no provision for keeping a record of the furs taken each year. In the case of some of the most valuable fur bearers—martens, fishers, wolverines, and otters—the situation has become so serious that the United States Bureau of Biological Survey has appealed to all State game and conservation commissions to protect them with a 5-year closed period, as the only way to forestall their extermination.

Fox farming represents the greatest development thus far in raising fur animals under strictly controlled conditions. It can still be considered a relatively new industry, since its development has taken place practically since the World War. The number of pelts so produced and sold in the United States is estimated to have increased from 6,000 in 1923, to 300,000 in 1938.

Foxes are grown successfully throughout the northern half of the United States, from New England westward to Washington and Oregon, and in the cooler parts of California. The greatest numbers of silver foxes are produced in Wisconsin, Minnesota, and Michigan, and these three States are contributing more than 50 percent of the annual crop of pelts. The two largest companies in the world producing silver foxes operate in Wisconsin. Each maintains about 7,600 breeding pairs. The other principal fox-farming centers are in the Rocky Mountain region, including Oregon and Washington, and in the New England States, Illinois, Ohio, New York, and Pennsylvania.

It has been estimated that the three leading countries in the production of silver foxes—Norway, Canada, and the United States—will produce during the 1938-39 season about 800,000 pelts; and that Sweden, the Netherlands, Denmark, the Union of Soviet Socialist Republics, Germany, England, France, Switzerland, Japan, and South America will contribute about 125,000 more pelts. This means that the world production of silver fox pelts for the season 1938-39 will very nearly reach the million mark.

It can hardly be doubted that this comparatively new fur-farming industry has become a permanent part of our agriculture. It has met with relatively more success in recent years than most other

branches of agriculture, and it promises still greater developments when freed from the artificial restraints and handicaps that at present are retarding its progress. Fur farming fits in well as a side line to general farming because it can utilize certain parts of the farm not adaptable to growing plant crops or other animals. It also provides a winter occupation and brings in additional revenue during the season when both are needed to balance farm operations.

PRESENT RESEARCH

Present research on fur animals deals primarily with the production, conservation, and utilization of these animals for food and fur. A survey of this research reveals that little has been done, however, by public agencies to develop fur animals as a natural resource, and there has been no systematic effort on the part of the State agricultural experiment stations to develop fur-animal production.

Without a vigorous conservation program based on sound scientific knowledge there is great risk of completely wiping out one of the oldest of the valuable resources of the country. On the other hand, fur farming is rapidly becoming an important farm enterprise. If it is to develop its full possibilities, however, further information is needed at various points. The industry is all the more significant because it does not compete with any other kind of farming.

The Department of Agriculture, realizing the commercial importance of fur in industry, has inaugurated a program of research the objects of which are:

1. To determine the demand for raw material.
2. To explore methods by which the supply of raw material may not only be maintained naturally in quantity but also be improved in quality.
3. To conduct research in the laboratory and on experimental farms in the production of fur animals for meat and fur.

These last two types of research include: (1) Genetics; (2) embryology; (3) feeds and feeding; (4) fur storage; (5) fur technology; (6) economic problems in management and operation; (7) statistics. This work has been accomplished through three fur-animal experiment stations operated by the Bureau of Biological Survey and also by cooperative studies with other agencies. Cooperative studies with other Federal agencies on particular phases of these problems are as follows:

4. Karakul sheep raising with special reference to fur production and technical studies of fibers of fur animals.
5. The influence of animal life factors upon the quality of the raw and tanned fur skins.

Cooperative studies with agencies outside the Federal Government are as follows:

6. Reproduction of the minks and muskrats.
7. Nutrition of foxes and minks.
8. Assaying livers of minks and foxes for vitamin A content.
9. Determination of the value of various North American furs for felting purposes.

SUGGESTED RESEARCH

Without extensive controlled experiments, all breeding and feeding practices are of a hit-or-miss nature. Experiments with fur animals are exceptionally costly, not only in the matter of equipment but also

in the time involved, for breeding stocks are expensive and practically all species produce only one litter a year. In addition, scientific training and the ability to conduct research are required, and the economic results of any given project are by no means certain. Private breeders are not likely to do much experimenting because they must confine themselves to operations that are fairly certain to produce immediate profits. Fur-farmers' organizations or wealthy producers might undertake some forms of research work, but men change their minds and associations change their policies, and under these conditions there is no assurance of continuity. There are many reasons why fur-animal research must be conducted primarily by properly equipped public institutions, but this can be done only in response to a sufficient public demand and with the active support of those who have a stake in the industry.

In order to place fur-animal production on a foundation comparable with that of other branches of agricultural production fundamental knowledge is essential, and this can be obtained only by a comprehensive program of research. Such a program must be organized to give more fundamental knowledge regarding several little-studied subjects. It should include the following:

1. Research to give more exact knowledge of the reproductive cycles of fur animals. Such knowledge could be applied in several ways. It would be of great value (1) in determining the proper trapping seasons for restoring and conserving fur animals, (2) in attempting intelligently to supplement the natural supply by restoring and transplanting, (3) in insuring success in producing fur species in captivity, and (4) in making possible a more efficient and economical control of predatory and other injurious species. The object of research on reproductive cycles would be to establish definitely (1) the breeding period of valuable fur animals, (2) the number of litters and young produced yearly, (3) the type of embryonic development (whether uninterrupted or with a delay in implantation), (4) the hormone control of the breeding cycle, (5) the feasibility of artificial insemination in those species that might be raised in captivity, and (6) possibilities for producing or maintaining reproductive fertility by hormone or other treatment.

2. Breeding experiments with various fur animals under controlled conditions. These should be conducted to study the inheritance of prolificacy and fur quality, which includes color, sheen, and density. In all animal breeding it is vital to concentrate on as small a number of objectives as possible. Measurements must be devised to evaluate all characteristics with greater certainty, especially those determining fur value. When genetic factors (genes) might be directly useful, as in the case of coat colors, they should be determined so far as possible. They will doubtless prove to be extremely complex, but research on color inheritance indicates that something may be done to segregate definite traits of this kind and to breed for them. Meantime, to use breeding stock of proved performance, as determined by the progeny test and by dependable records of parental characteristics, would be to approach the problem in the way that has proved to be of such great value in other branches of livestock breeding.

3. Research on digestion and metabolism of fur animals, the chemical composition of their foods, and the part played by various foods in growth, fattening, maintenance, reproduction, and the economical

production of pelts of high quality. Practically no research has been conducted along these lines. With few exceptions, fur animals are meat eaters. The maximum and minimum quantities of red meat that can be fed during the various stages of development should be determined. Similarly, there should be measurements for efficiency of feed utilization, since the cost of feeding is a large part of the cost of production. Some work has been done to determine the value of cereals, vegetables, and protein supplements in the ration, but it should be expanded. These and many more nutritional problems when adequately solved will enable fur-animal breeders to proceed more surely, safely, and efficiently.

4. Studies on the constituents of the hair and leather comprising fur pelts. Such studies should include physical and chemical analyses of the various parts of the fur skins to determine what they contain and how they are constructed. After this fundamental knowledge is available, and in some instances without waiting for detailed results, a variety of related studies should be made. Several types of such research have been strongly recommended. The chemical composition and physical character of fur of superior quality should be established first; then experiments should be developed further to determine influence of breeding, feeding, sex, age, season, environment, and type of animal upon the composition, structure, and quality of skins and their fur-making value. The problem would be to determine the factors and their interrelations that contribute to the production of fur of superior quality.

5. Practical studies relative to killing time, removal of pelts, and their subsequent curing treatments. These are needed for the better judgment of raw quality as opposed to the finished or dressed fur. A second important phase of this practical side is the economic utilization of the carcass either for animal food or as a source of raw material for other special uses such as animal fats and glandular products.

PART III. A COORDINATED RESEARCH PROGRAM

A presentation of the scope and general character of research work initially to be undertaken by the four new Regional Research Laboratories of the Department of Agriculture, under section 202, Agricultural Adjustment Act of 1938, in cooperation with other agencies, section 202 (c).

INTRODUCTION

A comprehensive research program to further the industrial utilization of agricultural materials is outlined in part III. The purpose of this part of the report is to outline in a condensed form the coordinated investigations to be undertaken initially in the four new Regional Research Laboratories in cooperation with existing Federal, State, and other research organizations, and the methods of approach that will be used. This part relates only to those commodities which the Department of Agriculture has designated for initial attention.

SYSTEMATIC CLASSIFICATION OF PROBLEMS

There are many thousands of tests or investigations that might be undertaken even if the list were limited to problems relating to only a few agricultural commodities. A random selection of projects from such a list would result in inefficient, if not ineffective, research. An orderly and carefully planned set of projects is necessary if at an early date any useful results are to be gained that may be promptly applied by industry for additional manufacture based on agricultural commodities. The research sections of part III undertake to outline as systematic an approach to the problem as can be presented at this stage. A more complete program will become possible as the details for the specific projects of the new Regional Laboratories are developed during the coming months.

In spite of the great variety of agricultural commodities, most of them are made up principally of certain common constituents—starch, sugars, protein, fats and oils, cellulose, and a few others which are less well known. A planned program of research takes advantage of this fact and arranges that much of the experimental work and engineering development will deal with these common constituents. The results of such a plan are, therefore, applicable in a practical way not to one agricultural commodity alone but to several.

The research work planned for starch is an excellent illustration of this relationship. Studies on starch made from corn might be so narrowly planned as to be applicable only to corn. Instead, the broader approach to the starch problem will be through study of the fundamental characteristics of all starches, as well as the particular characteristics of starch from individual commodities. The results, therefore, will be useful for corn, for wheat, for barley, for rice, and for other grains, and they may also be applicable to a large extent to starch produced from white potatoes, from sweetpotatoes, or from

other tuber crops. When such general results are available, their application to particular crops can be undertaken, and the most advantageous combination of raw material, process, and product will, it is hoped, result.

But while it is true that the bulk of most agricultural commodities is made up largely of a few common constituents, it is also true that the character of a commodity, the thing which lends it individuality and may largely determine its value, often rests upon the presence of one or more constituents which are peculiar to that commodity alone, or upon the existence of peculiar physical structure. Thus cotton is not valued so much because it consists mainly of cellulose as because of its very peculiar fiber structure. The marketability of a food product may depend more upon its flavor or texture than upon its content of protein, fats, and carbohydrates. New uses for agricultural commodities in the nonfood field may similarly turn out to rest upon the presence of a single peculiar constituent or of an individuality in structure.

Knowledge of these facts has been an important element in the development of orderly and systematic tentative programs of research to be prosecuted by the regional research laboratories in cooperation with existing agencies. The commodity and constituent sections which make up the body of part III have been divided generally into a small number of subprograms of research. While there are some individual differences, due usually to differences in the extent of present knowledge or in the volume of current research in different fields, most of the programs comprise the following types of research work:

(1) *Production research*.—Biological and agronomic investigation of the production of the commodity on the farm, in relation to the economics and the physical and chemical characteristics of the commodity. A more complete discussion of this type of research will be found in the following section, headed "Coordination and Cooperation."

(2) *Processing research*.—Improvement of the usual methods of processing the commodity in order to decrease the cost or raise the quality of the finished product, so that it may enter new fields of use.

(3) *Economic research*.—Determination of costs of production, processing, and distribution, of the location and character of surpluses, both in time and in place, and of the volume and value of prospective new outlets.

(4) *Analytical research*.—Chemical, physical, and biological determination of the composition and properties of the commodity and its products and byproducts.

(5) *Fundamental research*.—Study of the basic biological, chemical, and physical processes of nature for the ultimate purpose of control through understanding.

(6) *Applied research*.—The effort to produce new compounds, or new combinations of materials, or to process the commodity in new ways, for the purpose of extending existing markets or entering economically justifiable new ones for the commodity. Research of this type, starting on a small scale, grades insensibly into—

(7) *Development research*.—Investigation of the engineering and production problems involved in carrying promising new processes to the industrial scale.

A more complete discussion of the nature of those types of research work which have been called here "Fundamental," "Applied," and

"Development," will be found in part I of this report under the heading "Proposed Research Program."

COORDINATION AND COOPERATION

A second purpose of this part of the report is to show the principles of coordination of the proposed new research undertakings with the related research activities of the Department, of State experiment stations, of educational institutions, and of private research laboratories.

The act which establishes the laboratories directs such cooperation with other agencies, in the following language:

202 (c). In carrying out the purposes of subsection (a), the Secretary is authorized and directed to cooperate with other departments or agencies of the Federal Government, States, State agricultural experiment stations, and other State agencies and institutions, counties, municipalities, business or other organizations, corporations, associations, universities, scientific societies, and individuals, upon such terms and conditions as he may prescribe.

The primary concern of coordination is the effective use of research resources, consisting of personnel, facilities, and findings, in the accomplishment of mutual objectives. Planning of such coordination of the new work with that already in progress has been made possible by the comprehensive survey of present activities which has been reported in part II.

Both the chemical engineering and the pure science studies of the new laboratories will necessarily be tied in with studies of an agricultural nature. The work of the Department's soybean laboratory at Urbana, Ill., well illustrates this principle of coordination. The work of that institution and its cooperators includes genetic and agronomic studies on many varieties of soybeans, so that the laboratory workers have from the field experiments, which are carried out by the Department in cooperation with the State experiment stations, a product whose cultural history is fully known. When the laboratory studies are completed, it is possible to tell which varieties of bean, or which new hybrids, what methods of growth and fertilization, and what other factors, such as climate, soil, or weather, are important in producing a raw material that may be most advantageously utilized by new or expanding industry. Investigation of the chemical and physical properties of farm commodities in relation to use processing, on the other hand, may contribute to a better understanding of biological properties and give more specific objectives to those engaged in the biological phases of farm commodity production. Both the agricultural-research and the utilization-research programs may be stimulated and clarified by the contact.

The specific projects which will be assigned to the regional laboratories will take account of all such relationships in the hope that each new study undertaken may gain the maximum of momentum from present work, and that the laboratory may in its turn contribute through new experimental knowledge, new techniques, or clarified objectives to the effectiveness of work done by the cooperating groups.

Coordination of the projected new work with those research projects, dealing with new and extended uses for agricultural products, which are now being conducted in the Department will be a vital part of the development of specific projects for the regional labora-

tories during the coming year. Details of procedure must be worked out when the projects take concrete form but, in general, the method to be used is well established in the Department.

Two general principles of coordination are involved. First, there should be coordinated, cooperative effort to the maximum of effectiveness within the Department, and second, each problem should be vigorously and adequately attacked. Here again the purpose is to use effectively the resources of two or more groups in the attainment of a mutual objective. The usual method is to arrive at a definite agreement between the groups in conference with the Director of Research of the Department.

The research on industrial uses for farm products which has already been done in the Department has met with considerable success, as in the cases of agricultural wastes, casein, soybeans, lactose, and sweetpotatoes, to name only five of those which are currently active. The new legislation authorizes an important expansion of facilities for such work. It is the purpose of the Department to carry on an intensive attack upon the broad problem of finding new uses and new extended outlets and markets for agricultural products; in that attack, the new laboratories and the existing research facilities of the Department will mutually complement and supplement each other. The objective will be to utilize to best advantage all resources of trained personnel, accumulated information, proved techniques, and specialized equipment.

Related experimental activities of educational institutions and the laboratories of private industry, as well as those of the State experiment stations and of the other bureaus and divisions of the Department, are now known in considerable detail as the result of the survey reported in part II. Insofar as possible, the principles of coordination laid down in the preceding paragraphs will guide the planning of the laboratory program in relation to these private activities, just as they will in relation to existing State and Federal activities. The cordial cooperation given to the Department during the survey indicates that such coordination may be confidently expected.

The Department has already had long and gratifying experience with collaborative research efforts under the Bankhead-Jones and other acts of Congress, and its future experience will presumably be as satisfactory. The magnitude of the problem demands that the present harmonious relationships between the scientists and technologists in the Department and in the most diverse lines of outside research activity shall be maintained and strengthened, so that the invaluable expert knowledge of research workers throughout the nation may be effectively brought to bear.

LIMITATIONS OF SUGGESTED PROGRAM

During the design and erection of the new laboratory buildings, the Department expects that a much more detailed study of the research program will be carried out by the key members of the staffs of the laboratories, who are now being selected under civil-service procedure. It is fortunate that the senior members of these staffs can have several months for intensive study of the survey results and for further conferences with persons within and outside the Department before the complete staffs are chosen and the final selection of apparatus and equipment for the laboratories is made. During these

months this preliminary outline of the program will be matured and made more detailed for each commodity and for each phase of the work. It may be that some very important changes, even partial reversals of plan, may be necessary. This point is emphasized in order that those studying this report may not get the impression that the following sections present a finished or unchangeable program of investigation.

In formulating the programs presented, the controlling consideration of the Department has been to strive for new and extended uses of the products of agriculture. That objective, stated by Congress in the establishment of the new laboratories, usually requires that nonfood, and perhaps also nonfeed, applications of these commodities should be made. The general policy of the Department regarding these phases of the subject has already been presented in part I of this report. Part III should be read in the light of that statement of policy.

It should also be clearly understood by the reader that the Department will regard the ultimate success in research as best measured by practical industrial applications of results. Results of research represent merely a satisfaction of scientific curiosity, not a useful thing, until actually applied, especially when the projects relate to such practical matters as are being considered in this report.

LIST OF COMMODITY PROGRAMS

A list of the commodities and the more important constituents for which programs are presented is given below. Titles of the programs dealing with constituents are indented.

Corn:	Cottonseed: Vegetable fats and oils.
Starches and sugars.	Peanuts.
Motor fuels.	Apples.
Fermentation.	Fruits.
Wheat.	Citrus fruits: Pectin.
White potatoes.	Vegetables.
Sweetpotatoes.	Alfalfa.
Agricultural wastes.	Dairy products: Proteins.
Cotton fiber: Cellulose.	Tobacco.

COMMODITY RESEARCH PROGRAMS

CORN

The corn plant is an exceptionally efficient converter of solar energy and under favorable conditions is capable of producing large quantities of dry vegetable matter per acre. This characteristic of corn, together with its wide cultural adaptability and its favorable chemical composition, has established it as the prime feed grain of the United States and also contributed to its significant position as a crop of outstanding industrial importance.

A review of the production, disposal, and industrial utilization of the corn crop has already been given in part II. There it is pointed out that about 95 million acres annually are planted to corn, with a production of 2.5 to 3 billion bushels; that while about 90 percent of the crop is utilized for animal feeding, the portion of the crop sold has brought farmers a cash income during recent years of about 250

million dollars annually. About 70 million bushels of corn are wet milled annually for the production of approximately 700 million pounds of starch, 400 million pounds of corn sugar, 80 million pounds of dextrins, 1,000 million pounds of corn sirup, 130 million pounds of corn oil, and 570 thousand tons of gluten feed and meal. Thus, it is seen that corn already is being used extensively by industry, although the quantity so utilized is but a small fraction of the total crop.

In the utilization of the corn crop millions of tons of so-called waste material are produced annually in the form of stalks and cobs. A research program dealing with investigations of the utilization of these materials will be found under Agricultural Wastes in part III.

Corn as a grain is the most important domestic source of starch and such starch derivatives as corn sugar, corn sirup, and dextrins. Studies designed to extend the industrial uses of these and similar products are outlined in those sections of this part dealing with Starches and Sugars, Fermentation, and Motor Fuels.

Careful consideration given to present and suggested research on corn as outlined in part II has led to the development of the following broad research program on corn.

PROPOSED RESEARCH PROGRAM

Corn as a Raw Material

1. A critical, comprehensive survey of the technical literature on corn and corn processing and utilization will be undertaken. A complete summary of this type will furnish the basis for an intelligent laboratory approach to many of the problems involved in attempts to develop extended uses for corn, with a minimum duplication and a maximum utilization of work done to date throughout the world. This review may proceed effectively while the laboratories are being constructed.

2. Industrial utilization of corn will be studied as it may be affected by variation in the composition of germ, hull, and endosperm of the kernel with respect to starch, fat, protein, pigments, enzymes, and like substances, and the relative proportion of each of these constituents in different inbred lines, crosses, and strains. Such studies will also include the determination of changes in composition with variations in maturity, season, harvesting, drying, storage, weathering, disease condition, and age.

The genetic, agronomic, and pathological work which must be done in conjunction with these physical and chemical investigations will be performed in cooperation with and to a large extent by the existing facilities of the Department of Agriculture and the State agricultural experiment stations.

Milling of Corn

3. Design and use of laboratory equipment for study of dry- and wet-milling problems will be investigated. The program will include all phases of milling, such as tempering, steeping, degermination, grinding, screening, bolting, and related processes. Physical, chemical, or biological changes accompanying these various operations will be determined, and methods for their evaluation and control will be studied. Successful development of such equipment and processes is essential for the preparation of adequate uniform samples of starches,

proteins, oil, and byproducts for use in research projects dealing with new and extended uses of these materials.

4. Milling characteristics of various types, strains, and crosses of corn will be investigated in cooperation with the agronomic and genetic projects of the Department of Agriculture and the State agricultural experiment stations already under way in connection with various crop-production programs.

Byproducts

5. Investigations will be initiated dealing with the isolation and characterization of the proteins of the corn kernel, of gluten byproducts of milling operations, and of fermentation residues; determinations will be made of the physical and chemical properties of the isolated proteins and their derivatives with the objective of developing new and improved industrial uses of these materials. See also Proteins, part III.

6. Studies will be undertaken of variations in composition and characteristics of corn oil derived from different types of corn and produced by different methods of processing. Reactions and processes will be investigated with the objective of improving present uses and developing new outlets for corn oil. Attention will be given to the isolation and identification of glycerides, fatty acids, sterols, phosphatides, pigments, and odorous constituents, their effect on the properties of corn oil, and development of uses for these materials. Refer to Vegetable Fats and Oils, part III.

7. Investigation will be made of steep water, hydrol, and bran produced in the processing of corn with the objective of producing industrially useful materials.

Further industrial uses of corn are discussed under Motor Fuels, Starches and Sugars, and Fermentation.

STARCHES AND SUGARS

Starches from various sources (corn, potato, wheat, rice, tapioca) are basically the same, although the physical properties may differ widely and the composition apparently only slightly. A fundamental program on one starch—for example, corn or wheat starch—is also applicable in many respects to other starches. Except for uses due to special physical properties, the price of a starch largely determines the market outlet. The question of which starch is to be employed for commercial uses is therefore in part an economic one. Nonfood uses of starch and starch derivatives are many, and the amount annually consumed for these purposes in recent years has approximated half a billion pounds. Because of the excellent competitive position of starch in comparison with other refined raw materials on account of its price of $2\frac{1}{2}$ to 3 cents a pound, and because of the tremendous supplies available, a wide expansion of the present industrial utilization of starch seems almost inevitable.

Modified starches, dextrins, and glucoses are prepared industrially by heat, oxidation, and acidic or enzymic treatment of starches. The unique properties of these products have adapted them to many uses. Glucose, in particular, which is now made in the crystalline condition, has been diverted into many new fields. Glucose is related

to other sugars, such as sucrose, maltose, fructose, xylose, etc., which are constituents or can be prepared from components of farm commodities. Since similar methods are employed in studying and manipulating all sugars, a sound and efficient program should include investigations on sugars as a whole. However, the properties of these sugars are quite different, and in many cases they would not be expected to be utilized for similar purposes.

Progress in our knowledge of the starches and sugars has been slow because of the handicaps associated with (1) the great difficulty in obtaining pure compounds by crystallizations; (2) the lack of methods for obtaining structural information; (3) the difficulty in obtaining reaction with specific hydroxyl groups in large molecules; (4) the complexities introduced by isomerization phenomena; and (5) instabilities associated with the aldehyde group. The reactions involved in processing these materials industrially are depolymerization changes, hydrolytic reactions, oxidation reactions, and decomposition due to heat. The present methods of measurement used on modified starches and dextrins are generally arbitrary and have no significance outside of the laboratory making the determination. Since the physical and chemical properties determine the industrial outlets, fundamental information regarding such properties is required to facilitate expansion in this field and to develop new uses. An extensive and long-time research program should, therefore, be conducted on the biological, physical, and chemical properties of starch, modified starch, and simple sugar as an essential basis for developing new and extended uses.

PROPOSED RESEARCH PROGRAM

Starches

The following studies will be undertaken:

Agricultural research.

1. Effect of environment and of varietal and genetic factors on the deposition, structure, and composition of the starch granule and its constituents. This phase will be in cooperation with the related production research of the Department and State experiment stations. Of particular value in securing information on the structure of the starch granule will be microscopic, fluorescent, and X-ray investigations.

Purification and fractionation.

2. Relation of granule to kernel matrix; investigation of a possible change in state on isolation and purification of starch; preparation and comparison of starches from different species of plants, including studies to determine causes for differences in physical properties among starches of various origins; separation of starch from various sources into its constituents by new or refined chemical or physical methods under aqueous or nonaqueous condition; comparison of starch fractions and study of their relative importance in influencing the gross properties of starch. These investigations are designed to promote the rational extension of starch uses through clearer understanding and better control of its physical properties.

Analytical.

3. Development of physical and chemical methods for quantitatively estimating and identifying starch constituents and their simpler units; determination of the components of starches from various sources.

Physicochemical and colloidal.

4. Determination of properties of organized and disorganized starch granules and of starch, starch derivatives, and their solutions, such as viscosity, elasticity, etc. Such methods as osmosis, sedimentation, etc., will be applied and an investigation of molecular films made to obtain data on size and shape of starch molecules in order to establish a working basis for further studies in the development of new and extended uses.

Chemical.

5. Conversion of starch to derivatives by means of various techniques, such as esterification, oxidative degradation, phosphorylation, etc. Methods will have to be developed to change starch into polymeric derivatives. These studies are of particular significance in developing new uses for this class of compound.

Constitution.

6. Modification of surface of starch molecules, including molecular films, by chemical and physical means, and subsequent changes to secure information on the number and kind of groups on molecular surfaces. The number and arrangement of the glucose and other units will have to be determined by degradative and synthetic reactions. Modern concepts and physicochemical methods should be employed in the elucidation of the spatial configuration and structure of starch and of the primary and secondary valence forces. The nature and significance of trace constituents require investigation. All of these investigations on the constitution of starch have in view the deliberate modification of its properties in order to open up new possibilities of use.

Modified Starches, Dextrins, Gums, Etc.

Proposed investigations on modified starches, etc., are as follows:

Preparation.

7. Conversion of various starches to modified starches, dextrins, and gums by enzymic, chemical, biological, or physical treatment. Methods for controlling the hydrolysis of starch and for isolating intermediate and final products will have to be investigated, because of the possibility of wide utility for these substances if their properties can be fixed and the undesirable byproducts of hydrolysis eliminated.

Physical and chemical.

8. Determination of colloidal, physical, and chemical properties and development of methods for polymerizing modified starches and dextrins. These studies, in general, may be expected to be similar to those outlined above for starches.

Sugars

Studies on sugars will include:

Physicochemical.

9. Determination of properties of the various crystalline forms of glucose, fructose, xylose, etc.; of sucrose and maltose and their derivatives; of sugar solutions; and of mixtures of the sugars. Various physicochemical methods, such as spectroscopic, polarographic, etc., will be required in the search for structural information. Analytical methods for quantitatively estimating the sugars should be investigated. These studies are essential as a basis for developing new and extended uses of sugars.

Chemical.

10. Preparation of sugar derivatives and polymerized molecules by various new and improved chemical techniques. These studies are expected to lead to new industrial uses of sugars.

MOTOR FUELS

Civilization has been revolutionized by the development of the internal-combustion engine as a source of mobile and stationary power. In the United States, present fuel material for internal-combustion engines is practically limited to petroleum, of which our national reserves may be exhausted, according to present estimates, in perhaps 25 years under present increasing rates of consumption. Newly discovered petroleum deposits are estimated as not equaling present consumption, with seemingly lessening chance of future discovery of adequate reserve replacements. Replacement fuels from other sources must eventually be developed and brought into use. The importance of adequate supplies of fuel as items essential to national defense cannot be overemphasized. The possibility of supplying such fuel requirements from annually renewable agricultural crops or crop surpluses such as corn, white potatoes, sweetpotatoes, and wheat, by-products, or wastes might be of national benefit, not only for conserving present petroleum reserves, but also as a means of absorbing crop surpluses.

Alcohols and other chemical products suitable for use as fuels can be produced from agricultural materials by various methods, but under present economic conditions and present production methods such potential fuel materials are relatively expensive. The achievement of a replacement fuel industry on a national scale will very likely involve certain economic changes, and such an industry may have to be guided through a period of change and development.

Introduction of new types of fuels may considerably complicate present methods of distribution and may require standardization of all fuels sold for automotive purposes, because of the varying costs involved in the production of the several components of the fuels as well as in the production of any single component at different geographical points. Such production cost variations will be particularly important in fuels from agricultural sources, which cannot be limited to a single agricultural commodity but may be produced from any starch or sugar material or even from wood. The research should be applicable with modifications to a variety of materials. Relative costs of fuels produced from high-grade or low-grade corn or similar

raw material must be established. Cost of production of agricultural fuels must be related to a common basis so as to equalize geographic or varying raw-material limitations. The problem of commercializing new fuels in such a manner as not to disturb unduly the existing industry contains elements of special difficulty. Commercial progress both here and abroad in the improvement of fuels, and in the improved design of engines to utilize these fuels, must be constantly followed in connection with the laboratory research on this subject. Further careful review and appraisal in this connection may proceed effectively while the laboratories are being constructed and equipped.

PROPOSED RESEARCH PROGRAM

Liquid fuels.

1. Experimentation will be initiated dealing with the production of the simpler and more easily producible liquid fuels which can be manufactured from agricultural materials. Methyl, ethyl, and butyl alcohols may be specifically mentioned as probable starting points, but higher alcohols and related derivatives or compounds possess potential values and will be considered. Investigations of the production and use of other possible liquid fuels, such as colloidal solutions of starch, will be considered. These studies will include pilot-plant operations for the production of the various compounds concerned with the objective of developing adequate cost-of-production data, which depend for their evaluation not only on processing methods but also on the utilization of the byproducts of the processes involved. (See also Fermentation.)

Gaseous and solid fuels.

2. Carbon monoxide, hydrogen, and methane are producible from agricultural materials in various ways, and attention will be given to new and improved methods for their production. These may be employed as fuels directly or may be synthesized into other products for use in internal-combustion motors. Studies will be devoted also to the evaluation of processes for the production and direct employment of solid fuels, which may include such material as pulverized corn and wheat, starch, cellulose, lignin, carbon, etc., all of which are obtainable from farm materials. The use of such solid substances, however, will necessitate studies dealing with the design of suitable motors for their commercial exploitation as fuels.

Development, design, and testing.

3. Investigations dealing with the design of process equipment, with the objective of reducing manufacturing costs or achieving other refinements of the fuels under investigation, are of great importance. Reduction in capital or operating costs of plants designed to produce the motor fuels under consideration from agricultural materials will be of significance in the development of such fuels. Study of improved types of engines will be undertaken with particular reference to their adaptation to various fuels. Performance tests with motors in current use, as well as experimental types of engines using various fuels and blends, will be continuously under way. Studies of possible standardization of blended fuels will be initiated.

Fundamental investigations.

4. A broad program of studies dealing with the chemistry of combustion as it occurs in motors will be initiated. These studies will include the combustion characteristics of various experimental motor fuels and their blends, as well as investigation of the effect of added substances on the behavior of these fuels in internal-combustion engines. The information developed from such fundamental studies is of the greatest importance in the evaluation of the suitability of the various fuels for use in motors of different types.

Economic investigations.

5. Economic studies will be instituted on the use, distribution, and marketing problems of agricultural motor fuels. Attention will be given to the impact of such fuels on existing industry as well as to the effect of the development of possible future competition from fuels producible from other materials. Studies will be made of problems connected with geographic distribution and availability of agricultural raw materials suitable as sources for motor fuels and of the relations which govern locations of possible producing plants.

FERMENTATION

Scientific cultivation of micro-organisms to effect desired biochemical changes which result in the production of definite chemical compounds for industrial and other uses has been receiving increased attention during the past 40 years, and is now of considerable industrial importance. In general, carbohydrate materials such as starch or glucose, which can be derived from commodities such as cereals, white potatoes, and sweetpotatoes are employed in such fermentations as the starting substances from which a wide variety of chemical products is obtained. The nature of the new substances so produced is, of course, dependent on the starting material as well as on the particular organism employed, and on the cultural conditions used in conducting the change. Thus fermentation is a general research tool by which certain desirable but difficult and, in some cases, otherwise impossible chemical changes of carbohydrates and other organic compounds are brought about.

The many species of bacteria, yeasts, and molds available differ widely in their ability to effect the changes desired. Some micro-organisms can transform carbohydrate material efficiently to one or more of such various materials as gluconic acid, lactic acid, citric acid, sorbose, acetone, ethyl alcohol, butyl alcohol, etc. Many other organisms, however, are useless for one reason or another. In most of such instances the starting material, substrate, is transformed largely to water and carbon dioxide, leaving nothing of value. In other cases the rate of transformation is so slow and the conversion so inefficient as to preclude economic process. The selection or discovery of the most desirable species is therefore of the utmost importance. Investigation of the biochemical activities of various micro-organisms leads not only to the discovery of the most suitable organisms to be employed for a certain desired transformation, but also may result in the discovery of new and unexpected products. Of equal importance with the selection of the proper culture is the determination of the optimum conditions under which it may effect the most rapid and efficient change possible. It is necessary to study in each case the effect of the kind and amount of accessory nutrient materials, the concentration of the

substrate, the acidity of the culture medium, and many other factors which vitally affect the yield of product and frequently determine whether or not a given process can be employed successfully.

Much of the research in this field is highly empirical. The successful use of many fermentation reactions in industry has been brought about only through the most painstaking and diligent effort. Obstacles are frequently confronted for which no solution is possible in our present state of knowledge. In brief, this is due to our lack of a true understanding of many of the fundamental principles involved in the physiology of micro-organisms. These have to do primarily with the various phases of reproduction, growth, and the development of substances within the cell which are required to carry out or condition processes by which nutrients are transformed into metabolic products.

The need of such basic knowledge will become more and more accentuated unless fundamental research supplies the deficiency in some measure. Research of this character is difficult, time consuming, and may frequently appear only remotely related to a given problem. Nevertheless, such an approach holds the greatest promise for the eventual solution of many practical problems encountered in the application of fermentation reactions to the development of new and extended uses.

PROPOSED RESEARCH PROGRAM

Collection of micro-organisms.

1. Availability of an adequate collection of suitable micro-organisms is of first importance in the development of an intensive research program on the fermentation of agricultural commodities for the production of industrially useful materials. At the present time no representative collection of organisms including yeasts, molds, and bacteria is in existence in this country. Procurement and maintenance of such a collection will require an experienced staff. It will be necessary to carry on a continuous program dealing with the subculture and identification of the organisms in the collection, in order to insure the preservation of their desired biochemical activities. This phase of the research may well be started while the laboratories are being constructed and equipped.

Production of industrially useful materials.

2. A continuous experimental survey of the microbiological activities of the organisms collected will be undertaken. Particular emphasis will be placed on studies of the effect of environmental and nutritional conditions on the production of metabolic substances. Fermentations which offer potential industrial possibilities will be further investigated in greater detail in relation to development of new and extended uses of agricultural products and byproducts.

Pilot-plant operations.

3. Pilot-plant-scale studies of fermentation processes will be initiated when these processes give indication of industrial application. Such studies will include the design of special equipment, the evaluation of possible uses as well as the preparation of derivatives which have industrial possibilities.

Saccharification.

4. Broad investigations will be initiated dealing with the conversion of starchy materials into simpler fermentable forms such as maltose and glucose. These investigations will include biological agents as well as purely chemical hydrolysis. The saccharification process underlies many of the current industrial fermentations now in use but its chemistry is at present only vaguely understood. The development of cheaper methods of saccharification of starch is an important factor in the improvement of present methods of production of certain motor fuels from agricultural commodities.

Fundamental.

5. Fundamental chemical and physiological investigations of the biochemistry of fermentation processes, including various phases of the reproduction and growth of the organisms concerned, will be undertaken on a broad scale. Further knowledge in this field is badly needed and any clearer understanding of the reactions and processes involved should result, not only in the improvement of known fermentation processes, but also in the development of new and improved methods for the preparation of industrially useful materials.

The fermentative production of alcohols is dealt with in the program for Motor Fuels.

WHEAT

Wheat acreage, production relative to areas, farm income, types of wheat, crop disposal, surplus situation, and domestic consumption have been discussed in part II. There it is pointed out that on the average, 55½ million acres were planted to wheat during the 10-year period 1927-36, with an average annual yield of 658 million bushels; that wheat is the second most important cash crop of American farms; that most of the sound high-grade wheat grown finds its ultimate use in foods and feeds; and that the average export of wheat from the United States has declined markedly in the past 20 years.

The composition of wheat varies considerably, depending on variety and environmental conditions. Both soft and hard wheats are made up of approximately 2 percent germ, 14 percent bran, and 84 percent endosperm. The chief difference in chemical composition of soft and hard wheat occurs in the protein content, that of soft wheat averaging around 10 percent and hard wheat averaging around 13.5 percent. However, there is a considerable range in protein content in both these types. Starch content of both types is around 60 percent, with that of soft wheat ranging a few percent higher than hard wheat. Oil and ash content range slightly under 2 percent on the average, while fiber averages slightly over 2 percent.

From this brief statement concerning composition it is evident that, aside from utilization of the whole wheat kernel itself, industrial uses for wheat must depend primarily on the development of new outlets for starch and to a lesser extent for proteins and the derivatives of these compounds.

In the harvesting of wheat enormous tonnages of straw are produced annually. While some industrial uses for this material have been developed they require at present comparatively negligible quantities. Proposed research dealing with wheat straw will be found in the section of part III dealing with Agricultural Wastes.

Industrial products now manufactured from wheat, other than bread (using that term in a broad sense) and animal feeds, are relatively few in number and small in comparative tonnage. This is the consequence, in part at least, of the distinctive properties of wheat which facilitate its conversion into attractive and readily available food. Thus wheat flour is the only known plant product which can be converted into a paste or dough possessing the requisite ductility, elasticity, and other physical properties to facilitate the production of leavened bread of good texture. The fairly direct route followed by wheat and wheat products from the field to the dining table, the relatively small waste en route, and the ease with which sound normal food wheat can be stored and handled against periods of shortage are factors which have contributed to the importance of wheat in domestic agriculture.

Thus, as a cereal, it must be considered as a comparatively cheap food. At the same time, it must be regarded as a relatively expensive source of the conventional raw materials such as starch, proteins, and fats, commonly derived from cereals. To compete with other cereals in the field of industrial utilization and with corn in particular, wheat must either lend itself to the production of unique products that will command a proportionately higher price, or it must be protected by some sort of direct or indirect subsidy.

In developing a sustained, long-time program of industrial utilization of wheat it appears that an adequate and continuous economic survey must be maintained concurrently. Thus the fluctuating levels of demand for various types of bread, biscuit, and cake flours, and durum semolinas must be known, since these demands have a bearing upon the availability and, hence, the price at which wheats may be had for the industrial operations outside the food fields. In fact, the appropriate procedure in developing new industries will be to build the latter around those wheat types which are represented in the largest proportions after the food requirements of the United States have been met.

This economic survey also should be so maintained as to yield data respecting supplies of low-grade and damaged wheats that are not suitable for flour milling but might be useful in industry. Thus, for example, there have been substantial quantities of shrunken, lightweight wheat resulting from black-stem-rust epidemics during certain seasons. These epidemics do not appear every year, and moreover, plant-breeding practices give promise of substantially reducing the quantity of such rust-damaged grain by the breeding of rust-resistant varieties such as Thatcher, Apex, and other spring wheats. Local weather conditions fluctuate from season to season and result, in turn, in widely varying quantities of drought-shriveled, and of field-damaged grain. The combine harvester and the modified harvesting and threshing practices which are being introduced may influence the kind and nature of surplus wheats available in certain areas. Accordingly, such surveys must be maintained as a normal phase of sustained economic utilization of wheats in new industries.

From a consideration of present and suggested research on wheat as outlined in part II, the following program is designed to develop the industrial utilization of wheat.

PROPOSED RESEARCH PROGRAM

Wheat as a raw material.

1. Studies will be made of variations in content and properties of starch, protein, oil, pentosans, pigments, and other components of wheat as affected by genetic and environmental influences including disease resistance, earliness, soil types, climate, fertilizer treatment, and related effects. As with other crops, the genetic and agronomic work which must be done in conjunction with these physical and chemical investigations will be carried out in cooperation with related research of the Department of Agriculture and the State agricultural experiment stations in the field of commodity production.

2. Surveys will be carried out dealing with the characteristics of each wheat crop to determine wheat types in surplus over and above food requirements, together with data respecting supplies of low-grade and damaged wheats. Such surveys should yield valuable information concerning the physical and economic availability of surplus wheat for industrial utilization.

Milling of wheat.

3. Wheat-milling investigations will be undertaken dealing particularly with recovery of special types of flours or meals for possible industrial uses. Milling, decortivating, or peeling and degermination methods will be considered in an effort to effect the best utilization of all possible structures of the wheat kernel. Physical and chemical studies will be made on these fractions for the purpose of determining their industrial utility.

Starch and starch derivatives.

4. Physical and chemical investigations of the properties of wheat starch will be made to ascertain the possibility of developing specific industrial uses for this material and its modifications or derivatives. Production of starch from hard and soft wheats will be considered. Extensive studies will be carried out as outlined in the section of part III under Starches and Sugars. Wheat and wheat starch will also be considered as raw materials for investigation under the program presented under Fermentations and Motor Fuels in part III.

Proteins.

5. Studies will be initiated on the chemical constitution and physical properties of proteins from hard and soft wheat, including the preparation, isolation, and characterization of protein constituents and derived products of these materials. Special attention will be given to the development of adequate methods of analysis and to the application of methods developed elsewhere. See also the section on Proteins in part III.

Oil.

6. Wheat-germ oil will be investigated with particular reference to a study of both the glyceride and nonglyceride fractions. Study will be directed particularly toward the determination of sterols, vitamins, antioxidants, etc., present in wheat-germ oil, and the development of new and extended uses for these substances. See also the section on Vegetable Fats and Oils in part III.

WHITE POTATOES

A definite need exists for commercially practicable methods of utilizing, for other than direct food use, the annual supply of cull, and frequently second-grade potatoes, as well as providing means for handling a certain proportion of first-grade potatoes during years of large surpluses. In addition, the loss from diseased and frozen potatoes and spoilage during storage varies between 5 and 10 percent of the crop, most of which could be saved by prompt utilization.

The fact that somewhat over two-thirds of the potato consists of water has always made it difficult for this crop to compete as an industrial raw material owing to excessive transportation and storage costs and to the large losses resulting from spoilage in storage. Recent researches on the development of low-cost dehydration methods have indicated that it should be possible to reduce both storage and transportation costs.

Starch manufacture with adequate recovery and utilization of by-products and the manufacture of accessory products, such as specially modified starches, oxidized starches, dextrins, plastics, etc., in demand by various industries would seem to be a practicable means of utilizing surplus and cull potatoes.

Development of a profitable means for the industrial utilization of potatoes differs somewhat according to the character of the various potato-growing regions. For example, although the chemical composition of white potatoes in the far western region differs somewhat from that of white potatoes in the northeastern region, from the standpoint of industrial utilization the outstanding difference between the two regions is the occurrence of large areas of high density of potato production in the northeastern region, notably in northern Maine, whereas in the far western region such dense areas are comparatively small. In the far western region the problem of transportation of potatoes to central points for industrial utilization is the "bottle neck," so to speak. Primarily for this reason, no potato-starch industry has been established there whereas such an industry has been in existence in northern Maine for many years.

Domestic potato starch factories are generally operated without chemical or other control. The percentage of starch recovered is quite low, an excessive amount being lost in the residual pulp and waste water. The equipment is to a great extent crude, and, because the quality of the starch manufactured is quite variable, the price is reduced below that of imported potato starch, which is preferred by many users even at a higher cost. Much improvement in domestic methods of processing is possible both in economy of operation and improvement of starch quality. Establishment of this industry on a sound competitive basis should provide an expanding and profitable market for culls and the surplus portion of the crop.

The following program, which is based on careful consideration of current research activities and Survey suggestions outlined in part II, has this aim for its objective.

PROPOSED RESEARCH PROGRAM

The following studies to increase the industrial utilization of white potatoes will be undertaken:

Agricultural.

1. Effect of varietal, cultural, and environmental conditions on the chemical composition of potatoes and on physical and chemical properties of potato starch. These studies will be most effectively performed, and duplicative effort minimized through cooperative arrangements with other Federal and State agencies which have the necessary facilities already available for cooperation in the production phases.

Storage and dehydration.

2. Development of low-cost dehydration processes, as well as other means of lowering transportation and storage costs. Variations in the composition of potatoes under different storage conditions will be studied and the information utilized to develop optimum conditions for preserving potatoes for industrial uses.

Potato processing.

3. Laboratory- and pilot plant-scale operations to develop improved methods for the manufacture of a uniform, high-quality potato starch; development of improved methods for microbiological control of processing operations; development of methods for economical processing and recovery of potato starch from frozen and otherwise damaged potatoes; and small and pilot plant-scale investigations on methods and equipment for the economical recovery of byproducts from potato-starch manufacturing operations.

Potato starch and development of new products.

4. Determination of the physical and chemical properties of potato starch and potato starch derivatives and the use of these data in the solution of specific problems in the industrial application of such products. Chemical, physical, and microbiological investigations on the production of specially modified potato starches and potato-starch derivatives, such as oxidized starches, dextrans, etc.

These studies have been described on a broader basis in the section on Starches and Sugars, part III.

SWEETPOTATOES

Sweetpotatoes are the second largest vegetable crop in the United States, production in 1937 amounting to over 75 million bushels, having a farm value of about 65 million dollars. About 80 percent of the 1937 crop was grown in the Atlantic and Gulf States from North Carolina southward.

Because the food market for sweetpotatoes is somewhat inelastic, large surpluses of first-grade potatoes are certain to occur during years in which high yields are obtained. Moreover, because of the strict grading requirements for the food market, large quantities of culls occur annually. These consist largely of over-size potatoes which in the South amount to about 20 percent of the crop.

The sweetpotato merits special consideration as an important factor in the development of southern agriculture because of its great suitability to southern soil and climate, and because it has the possibility of becoming the lowest cost and highest yielding producer of starch per acre of all crops grown in the United States. Further, this crop may possibly assist in relieving cotton surpluses by replace-

ment of cotton acreages. The market for starch and starch derivatives is very extensive and when fully developed should be capable of affording an outlet for many hundreds of thousands of acres of agricultural production. It should be pointed out that while sweetpotato starch has certain properties which make it especially suitable for certain purposes, nevertheless competition with other domestic starches will inevitably occur with expanded production of this product.

The research required to establish a new industry is necessarily extensive and embraces many phases. The first successful effort to accomplish such an objective was brought about through the establishment of a starch factory at Laurel, Miss., in 1934, in which the Department of Agriculture cooperated technically. Although some progress has already been made in establishing a sweetpotato starch and byproduct feed industry, much research which cannot be accomplished with funds now available remains to be done. Some of the most urgent of these problems are as follows: The development of higher starch content varieties; improved methods of growing and harvesting sweetpotatoes; the development of low-cost dehydration and storage methods to minimize the disadvantageous perishable nature of sweetpotatoes; technological improvements in the manufacture of sweetpotato starch to lower production costs; development of new and wider industrial applications of sweetpotato starch and derivatives.

PROPOSED RESEARCH PROGRAM

Looking to the solution of these problems, the following program of research is proposed:

Agronomic.

1. Studies on effect of varietal and environmental factors on the chemical composition of sweetpotatoes and on the physical and chemical properties of sweetpotato starch; and influence of other factors such as spacing of plants, fertilizer applications, etc., on the composition of the tuber. Effect of planting and harvesting dates on the yield of sweetpotatoes per acre will receive attention. Of particular importance will be the development of planting and harvesting equipment suitable for small-scale and for large-scale farming operations in the growing and harvesting of sweetpotatoes for industrial uses.

For the conduction of this work it is planned to establish cooperative relationships with agencies in the Department of Agriculture, the Laurel, Miss., starch project, and those interested State experiment stations which have facilities already available, to the end that duplication of effort will be avoided.

Storage and dehydration.

2. Studies on low-cost storage methods for the purpose of increasing the period of operation of processing plants will be developed. Storage methods investigated will include: Dehydration by means of chemical treatment followed by the removal of water by mechanical means; storage under water in the presence of suitable preservatives; and other means of storage which may be originated during the course of investigation.

Processing.

3. Studies on development of improved and simplified low-cost procedures for the manufacture of a uniform, high-quality sweetpotato starch which will involve both laboratory and pilot-plant-scale experimentation to work out the various mechanical details of operation as well as to determine the most satisfactory types of mechanical equipment for the processes concerned; the establishment of necessary microbiological control methods in the starch manufacturing process; the possible use of micro-organisms to liberate additional quantities of starch from the plant tissues after completion of the conventional grinding and screening processes; the development of methods for the economical recovery of byproducts.

Sweetpotato starch and new products.

4. Studies on the physical and chemical properties of sweetpotato starch and sweetpotato-starch derivatives; the industrial applications of sweetpotato starch and its derivatives with the object of expanding market outlets and increasing the value of the raw materials, the production of modified sweetpotato starch, and of sweetpotato starch derivatives by chemical and other means.

For a more detailed discussion of research problems see Starches and Sugars, part III.

AGRICULTURAL WASTES ¹

Between 165,000,000 and 200,000,000 tons (dry basis) of agricultural wastes are produced annually as a byproduct of the important agricultural crops. This is equal in weight to approximately 35 to 50 percent of the annual production of coal; 100 percent of the annual production of petroleum; and 3 to 4 times the annual consumption of human food.

As a rule, agricultural wastes are allowed to rot in the fields or are plowed under, but sometimes the farmer burns them in order to dispose of the large amounts that remain after the minor needs for feed, fuel, bedding, litter, and other farm purposes are taken care of. Small amounts of agricultural wastes (less than 1 percent) are used in industry, principally in the strawboard and straw-paper industry, in the insulating-board industry, and in the manufacture of furfural.

Failure to use the major portion of this immense tonnage of fibrous material in the manner most profitable and efficient for the farmer is serious. The benefits of returning mineral constituents, organic matter, and humus to the soil through the medium of agricultural wastes are not questioned, but when these materials are left indiscriminately in the fields, insect pests and fungus and other plant diseases become very difficult to eradicate because the continuously available source of nutrients provides a fairly satisfactory medium of growth.

The problem of utilizing agricultural wastes satisfactorily is challenging because of the enormous quantities involved and the possibilities for producing therefrom structural, insulating, and decorative materials, pulps, papers, plastics, feeds, fuels, fertilizers, chemicals, and many other valuable materials.

¹ The term "agricultural residues," although not so commonly used as "agricultural wastes," would be more exact. Cereal straws, for instance, play a definite part in the farm economy, even though the proportion actually used is minor.

To arrive at a wholly satisfactory solution of the problem, however, it is obvious that the diversion of a large percentage of wastes to industry should not curtail or impair the productivity of the land.

Establishment of industries using an appreciable percentage of the immense tonnages of agricultural waste materials now produced annually would provide employment for thousands of people. Several types of industrial application should be possible. Some of the processes developed should be suitable for use in urban industrial centers and others for use in rural areas or by cooperatives, while still others might provide occupation on the farms.

It should be pointed out that one of the main draw-backs in the utilization of agricultural wastes is the cost of collection and assembly at central points. For this reason, collection, harvesting, and storage will be given full consideration. Moreover, whatever program of research is adopted must include not only studies on harvesting, collecting, and storing the agricultural wastes themselves but also similar studies on the basic crop as well.

The proposed program on agricultural wastes has been classified under the following subheads: (1) Collection and storage of crop byproducts; (2) fundamental studies—(a) general and biochemical studies, (b) studies on lignin, (c) studies on hemicelluloses (pentosans and hexosans) and derivatives; (3) utilization of crop byproducts—(a) composting and soil enrichment, (b) building and other insulating materials, (c) pulping, (d) fermentation, (e) plastics, (f) destructive distillation, and (g) miscellaneous uses.

COLLECTION AND STORAGE OF CROP BYPRODUCTS

The use of agricultural wastes as raw materials has been urged repeatedly. The chief arguments advanced for this use are the inherent low cost of the raw materials, the vast annual production, and the present lack of utilization. Only a few of the crop byproducts classed as agricultural wastes are used in industry. For the most part, the ones now used are concentrated at a given point in the normal handling of the basic crop, making them available in quantities and at costs which encourage industrial utilization. The use of oat hulls for the production of furfural is an example. The initial cost of agricultural wastes "in the field" may be only a small part of the cost "f. o. b. factory." The expense of harvesting, collecting, and storing may take them out of the class of low-cost raw materials.

The economical segregation and collection of agricultural wastes therefore is of paramount importance in connection with any broad program directed toward their utilization. This is necessary in order to make these wastes available with the full advantage of their inherent low cost.

PROPOSED RESEARCH PROGRAM

The following broad project should facilitate the solution of many problems associated with the collection and storage of agricultural wastes.

Chemical, engineering, biological, agronomic, and economic studies relating to the harvesting, collecting, drying, pressing, compacting, baling, handling, piling, storing, covering, protecting, transporting, or partial processing of agricultural wastes, including work directed

to the prevention of undesirable changes and promotion of desirable changes during any step. Many phases of this work will be carried out in cooperation with Federal and State agencies which are active in production research.

FUNDAMENTAL STUDIES

Fundamental research on agricultural wastes has not been greatly emphasized, although in a few instances fundamental studies have produced very significant results. The production of furfural from corncobs and oat hulls is an example. Much of the present utilization of agricultural wastes, however, is along lines that are more or less obvious, for instance, in making paper, board, and structural insulation from straws, stalks, and bagasse.

Successful and comprehensive utilization of agricultural wastes requires primarily a critical scrutiny of these materials in order to ascertain their structure and composition. Results of such studies not only should point the way to broader utilization in fields already opened but should open new avenues of industrial application.

While these fundamental exploratory investigations, dealing with structure, composition, etc., will necessarily precede the investigations using the information thereby obtained, there will also be concurrent fundamental investigations dealing specifically with individual components and aggregates. These studies will be devoted to such components as lignin and hemicelluloses, discussed later in this section, as well as fundamental studies on cellulose and pulping, discussed under these heads.

GENERAL AND BIOCHEMICAL STUDIES

Fundamental investigations along general and biochemical lines will be of great value in the planning as well as in the continuous pursuit of the various subdivisions of research on agricultural wastes outlined in this section. It would, in fact, be highly desirable to have definite results from many of the following studies at an early date. For this reason, it may be necessary to approach this portion of the research with the idea of serving best the interests of the other closely correlated investigations. The sequence of these studies will, therefore, be governed by expediency.

PROPOSED RESEARCH PROGRAM

Research of the following type will be conducted:

Fundamental agronomic, chemical, and biochemical studies relating to the structure and composition of agricultural wastes, including their content of cellulose, lignin, pentosans, and minor components, together with investigations of the mechanism by means of which these components are synthesized, and methods for controlling the percentage of the various components. To the extent of practicable effectiveness these phases will be in cooperation with related research in production.

STUDIES ON LIGNIN

As lignin is present to the extent of about 25 to 30 percent in agricultural wastes, such as cereal straws, corn stover, and corncobs, it is evident that tremendous quantities of this material are available for

industrial use. With the exception of coal, lignin is the only large natural source of aromatic material of the benzene type available in the world. When our coal deposits are depleted, therefore, if not before, lignin will necessarily be employed to supply the huge industrial demands for aromatic compounds. Although lignin presents potentialities comparable with those inherent in coal tar a century ago, not much success has attended the search for utilizing it industrially, either as such or in the form present in waste sulphite liquor from pulp mills. Nevertheless, because of the cheapness of the raw material from which it is obtained and the large amounts available, the possible industrial utilization of lignin is still the subject of considerable interest. Perhaps the main barrier to the successful solution of this problem is our inadequate knowledge regarding the isolation, composition, and structure of lignin, as well as the lack of tools for economically converting it into useful products.

PROPOSED RESEARCH PROGRAM

A coordinated research program designed to lessen the difficulty of preparing lignin and to determine its chemical composition is urgently needed to provide a firm basis for carrying out further studies on the utilization of this material.

The following studies will be undertaken:

1. Development of economic methods for the preparation of lignin from farm wastes. This investigation would involve the isolation of lignin from the different farm wastes by new or modified methods. The successful conclusion of this laboratory work would be followed by work on a pilot-plant scale.

2. Investigations on the chemical structure of lignin. A comparison of lignin from various sources should be made in order to determine whether the structures differ. Physical and chemical studies will be required to furnish knowledge on the size of the molecule and the nature and arrangement of the simplest units of which the molecule is composed.

3. Degradation or modification of lignin by chemical methods. New reactions for converting lignin to relatively simple materials will have to be developed and methods devised for separating these products. Conversion studies should be conducted to prepare various modified lignin derivatives having roughly about the same molecular complexity as lignin. Reactions leading to the polymerization of lignin are particularly important as subjects of investigation.

4. Utilization studies of lignin or lignin derivatives for the production of plastics, textile sizes, antiwetting agents, adhesives, etc. Lignin should be investigated as a source of simple compounds for use in the synthetic chemical industries or as bases for insecticides. Information obtained in studies outlined in sections 2 and 3 would provide a working basis for attacking the utilization problem. Promising results in this field would be subjected to pilot-plant operation.

STUDIES ON HEMICELLULOSES (PENTOSANS AND HEXOSANS) AND DERIVATIVES

Approximately 20 to 35 percent of the dry matter of farm wastes such as cereal straws, corn stover, and bagasse is composed of hemicelluloses and related materials. Since this type of waste is not used industrially at present, vast quantities of raw materials are available

for the production and possible industrial utilization of hemicelluloses or derived products (xylose, furfural, etc.). Hemicelluloses are mainly composed of combined sugars and are, therefore, related to starch and cellulose.

Hemicelluloses and pentosans have received less attention than any of the other main constituents of agricultural wastes, and little information is available either on laboratory methods of preparing them or on their constitution and properties. At present they are not employed commercially as such, and the development of industrial uses no doubt has been handicapped by lack of precise chemical data concerning them. The meager information available indicates that their properties are not only quite different from those of lignin, proteins, cellulose, fats, etc., but also of such a kind as to suggest the wide utilization of those materials after suitable modification for novel industrial uses.

Xylose, Arabinose, and Uronic Acids

Mild acid hydrolysis of hemicelluloses and pentosans yields pentose sugars and sugar acids. Xylose, which is usually present in large amounts, has been prepared on a pilot-plant scale at a cost of about 25 cents a pound. Owing mainly to the lack of markets, attempts to commercialize this product have failed. It might possibly be produced commercially if the cost of production could be reduced to approximately that of the other commercially available sugars. Further fundamental and practical studies on xylose are expected to point the way to the development of new uses. The possible industrial utilization of arabinose and uronic acids has received practically no attention.

Furfural

Appropriate chemical treatment of farm wastes converts the hemicellulosic constituents to furfural, which can be easily separated in the pure form. Furfural is now produced commercially from oat hulls. Although work on this phase of the utilization problem seems unnecessary, additional fundamental and utilization studies are required to expand the present uses of furfural.

PROPOSED RESEARCH PROGRAM

A comprehensive program will be required to obtain the necessary fundamental and engineering data for the utilization of hemicelluloses and their derivatives. This will involve:

Hemicelluloses, pentosans, and related materials.

1. Investigations on small- and large-scale production of hemicelluloses and pentosans from the different types of farm waste: Hemicelluloses from various sources should be purified and compared to determine whether or not they are homogeneous.

2. Structural studies employing physical and chemical methods: Information to be obtained includes the size and shape of the molecule, type of binding, and kind and arrangement of structural units within the molecule.

3. Chemical investigations to determine the properties of the hemicelluloses and pentosans: The behavior of this class of compounds and

their derivatives toward chemical agents inducing polymerization should receive attention.

4. Utilization studies on derivatives having potential industrial application, including pilot-plant operations on promising products.

Xylose, arabinose, and uronic acids.

5. Production studies on a pilot-plant scale: Economical methods for preparing xylose will be emphasized. Byproduct utilization will require investigation. Results obtained in proposed studies in section 2 will indicate whether the quantities of arabinose and uronic acids in some types of hemicelluloses and pentosans are large enough to be of practical significance.

6. Fundamental investigations similar to those outlined for sugars in Starches and Sugars, part III.

7. Practical studies on xylose, arabinose, and uronic acids: Various derivatives will be prepared and their properties investigated. Initiation of pilot-plant studies will depend on the industrial promise these products show.

Furfural.

8. Fundamental investigations: Chemical studies on furfural and its derivatives are proposed. Study of the physical effects of furfural and its derivatives on gases, liquids, solids, and colloidal systems should yield significant results.

9. Utilization studies: The polymerization of furfural by various agents will be investigated. Data obtained in section 8 will determine the direction other utilization work will take.

UTILIZATION OF CROP BYPRODUCTS

Composting and Soil Enrichment

Farm wastes not employed directly for industrial or other purposes should be returned to the soil in a satisfactory form. This practice would at least partly restore the mineral constituents removed from the soil by plant growth, replenish the organic matter consumed in various soil activities, and reduce the propagation of plant pests by removing breeding places provided by wastes decomposing in the open. The maintenance of organic matter in soils is of considerable significance in retaining soil productivity, reducing erosion, decreasing leaching, and influencing the fixation and availability of plant-food materials. The practice of burning farm wastes or allowing them to remain on the field should be condemned as vigorously as the maintenance of the productivity of the soil by the maximum utilization of organic wastes should be encouraged. This change in farm practice is urgently needed if the soil is to continue to be our most important natural resource.

For economic reasons, this program will consider not only the processing of organic wastes for the production of artificial fertilizers but also the direct utilization of agricultural wastes in the soil.

PROPOSED RESEARCH PROGRAM

Research on composting and soil enrichment should include fundamental studies of two different types, depending on whether the artificial manures are to be employed in areas under large-scale cultivation

or in areas under limited and scattered cultivation. Under the former conditions, composting might be done most economically at centrally located plants, receiving wastes from farms within a limited radius and distributing the finished product at a nominal cost to consumers. Under the latter conditions, where the collection of large quantities of wastes would be uneconomical, procedures would have to be developed to meet the needs of the individual farmer. The economic phases of the problem would require serious consideration.

Proposed studies comprise:

1. Fundamental studies on the biological and chemical changes that take place in the composting of farm wastes or their constituents, and in soil to which various types of organic matter have been supplied. The role played by the different micro-organisms or symbiotic combinations of them in converting cellulose, lignin, and hemicellulose into humus and plant nutrients should be determined. Possible decomposition or synthesis of plant-growth hormones during the composting process also requires attention.

2. Investigations on bin, trench, and sheet methods of composting. Different types of farm wastes should be composted on a scale adapted to the farm, and the results compared from the standpoint of efficiency.

3. Studies on the feasibility of composting farm wastes on a pilot-plant scale.

4. Investigations on direct utilization in the soil of crop residues, with or without the simultaneous addition of fertilizer. The most efficient and practical methods of utilizing and distributing farm wastes under varying climatic conditions and in various soil types should be determined. Cooperation with related research of the Department and State experiment stations will be arranged.

Building and Insulating Materials

Building and insulating materials made from agricultural wastes can be divided into the following classes: Wall board, insulating board, insulating blocks, insulating quilts, and insulating fill. These classes are well known in the building trades.

Some of the important properties desirable in an insulating material are (1) low thermal conductivity; (2) structural strength; (3) water resistance; (4) vapor resistance; (5) fire resistance; (6) proper acoustical properties; (7) permanence; (8) resistance to insects, vermin, fungi, and other agencies of decay. Since the possession of all these characteristics is to some extent inconsistent, most materials and products manufactured represent a compromise to meet a definite need or to use a certain raw material.

PROPOSED RESEARCH PROGRAM

The studies will include:

1. Agronomic, chemical, engineering, biochemical, and other investigations on the structure and composition of the wastes themselves as raw materials for building and insulating materials, in order to select the most appropriate outlet for any particular material. In this phase cooperation with related production research of the Department and State agricultural experiment stations will be arranged.

2. Chemical, engineering, and related studies devoted to preparing, forming, and finishing the products.

3. Chemical, physical, and other research pertaining to physical properties, such as strength, stiffness, hardness, and density, and the correlation of these properties with thermal conductivity and sound absorption, and with the individual fiber, filler, and binder characteristics.

4. Chemical, physical, and biological investigations on the development of special properties, such as water resistance, vapor resistance, fire resistance, and resistance to decay and insect attack, together with investigation of the possible toxicological effects of any of the proposed treatments.

5. Investigations of the type covered by the preceding sections but directed to the production and use on farms and in rural areas, of building materials made from agricultural wastes alone or in connection with nonagricultural materials.

PULPING

Pulping of agricultural wastes can very profitably be the subject of considerable research. As a rule, agricultural wastes are in a very different form from wood, the comparable raw material. They are usually light and voluminous, and pulping them requires larger cooking capacity and higher liquor-to-solid ratios but less drastic chemical treatment than are required for pulping wood.

The materials themselves, even a single stem or stalk, vary more than wood chips in physical and chemical composition. Different portions, such as the nodes and the sections between, respond to the pulping action at different rates. It seems logical, therefore, that the study of pulping procedures for agricultural wastes should be undertaken with the object of finding a procedure specifically adapted to the materials in question.

A number of industrial, governmental, and educational agencies have well-developed research programs which include some of the projects described below. These programs will receive recognition to avoid duplication of lines of research now being adequately followed. It should be understood, therefore, that only certain portions of the following broad program will receive initial attention. Those portions now being adequately investigated by other agencies will not be studied.

PROPOSED RESEARCH PROGRAM

The following studies will be undertaken:

1. Chemical pulping studies to evaluate the nitric acid cooking process. This research will include the following investigations: (1) Studies designed to reduce the net percentage of nitric acid by decreasing the time of treatment and increasing its effectiveness by the use of continuous apparatus and also by the use of auxiliary agents, such as alcohols and urea, or combinations that will promote, accelerate, or control the action of the nitric acid; (2) concurrent studies on the secondary or alkaline stage of this cooking process; and (3) development and application of analytical, recovery, and fortification methods to permit continued reuse of the nitric-acid liquors.

2. Chemical pulping investigations employing volatile, alkaline compounds, such as ammonia, and the recovery of lignin and reuse of ammonia.

3. Fundamental chemical studies on solvents for the principal constituents of agricultural wastes (cellulose, lignin, and pentosans). These studies should be directed to the development of a process or processes particularly adaptable to the pulping of agricultural wastes, with due regard for all the characteristics of the raw materials as well as the yield and quality of the products. These investigations may develop a method for the direct solution of the cellulose in agricultural wastes and its regeneration as such or in the form of derivatives.

4. Chemical engineering studies directed to the development of apparatus and equipment embodying or utilizing the principles established in the preliminary, fundamental, or applied research. These studies will be followed by pilot-plant-scale work.

5. Chemical engineering and other research to adapt present manufacturing processes to the fibers and pulps having special or outstanding characteristics. This work will include efforts to recover and find uses for any byproducts of the pulping processes developed.

Fermentation

Fermentation studies applied to the production of utilizable products, gases, and residues from agricultural wastes, are actively under way. This work, especially that portion which has to do with the production of fuel gas on the farm, has received extensive and perhaps premature publicity. As a result, many people have been led to believe that the problem was solved, whereas much fundamental and developmental work must still be done before the best results are achieved.

PROPOSED RESEARCH PROGRAM

Fundamental and applied zymological, chemical, and engineering research will be conducted to study organisms known to attack or suspected of attacking or decomposing agricultural wastes; to study the products of biochemical activity; to develop methods of promoting, enhancing or controlling the products of such activity, or to find methods of producing new products; to design apparatus, equipment, and processes for laboratory or pilot-plant scale work on this project; to find new uses or outlets for any of the products or residues resulting from the processes developed. (For further details, see Fermentation, pt. III.)

Plastics

Developments in the plastics industry in the past few years have been amazing. These developments have resulted from intensive engineering work on pressing equipment as well as from improved properties and widened varieties of molding powders. The combined effect has been to lower the cost, improve the general properties and appearance of plastic products, and increase acceptance of plastics in everyday life. In the manufacture of fairly complicated small articles, the fabricating costs of which are high, plastic materials can outdistance most competition. However, in the manufacture of larger articles, such as furniture or structural materials, the cost and consequently the acceptance, will be governed very largely by the cost of the materials from which the molding powders are made.

Agricultural wastes have shown considerable promise in the production of low-cost plastics. Their use for this purpose would not only

provide an outlet for them but would make possible important improvements in building and furniture construction.

PROPOSED RESEARCH PROGRAM

Fundamental and technological, chemical, and engineering investigations will be instituted to study, develop, and apply methods of preparing molding materials from agricultural wastes or any component of agricultural wastes, such as lignin, by acid or alkaline hydrolysis or other methods; to study the different operations necessary in their preparation; to investigate various aromatic amines and aldehydes and other chemicals used as plasticizers, or to promote, assist, or control any step in the formation of the plastic; to study and develop processes, apparatus, and equipment for pressing, molding, curing, or otherwise forming or fabricating plastics from agricultural wastes whereby the molding powders developed may be used or the structural and decorative properties improved or the costs of production reduced.

Destructive Distillation

The destructive distillation of agricultural wastes and the production of fuel gas, tars, carbons, and other materials have been given considerable thought by those interested in agriculture, and they have also been the subject of some research.

From time to time, retorts intended for the production of fuel gas on the farm have appeared on the market, but at present they are not being used extensively. The pyrolysis process is not fully understood, and its possibilities have not been evaluated. With a better knowledge of destructive distillation, and with means for controlling the process and to a certain extent determining what will be produced, it may be possible to establish a paying industry. Owing to the fact that control and supervision are required and are usually more costly for small than for large installations, it will probably be more difficult to develop a small-scale process for use on farms than it will be to develop larger processes.

PROPOSED RESEARCH PROGRAM

Fundamental and applied chemical and engineering research will be conducted to establish optimum conditions of time, temperature, pressure, and chemical environment in the pyrolysis zone for the production of maximum yields of the usual products or for the production of new and more valuable products; to isolate, identify, and find uses for existing and new products or modifications thereof; to investigate and design new, more efficient, and more easily controlled equipment for destructive distillation and the recovery and utilization of the products.

Miscellaneous Uses

Man's efforts to use fibrous materials, such as agricultural wastes, are probably older than the practice of agriculture itself. It is not surprising to find, therefore, that these materials have been put to many varied uses. A program designed to develop uses other than those considered elsewhere in this report is outlined below.

PROPOSED RESEARCH PROGRAM

Proposed studies consist of fundamental and applied chemical, engineering, and other investigations to study, develop, and apply scientific principles in adapting agricultural wastes to the following miscellaneous uses:

1. As fillers for plastics and rubber: The effect of the properties of the fillers upon the strength, density, curing, molding, finish, water resistance and chemical resistance, and other properties of the finished articles should be considered.

2. As raw materials for briquetting, per se or in connection with products such as low-grade coals, lignite, and tars from destructive distillation, for low-cost and easily transported fuels.

3. As raw materials for the production of masses less dense than briquettes. These can be made on the farm for use there or for use locally as fuel or for other purposes.

4. As fillers for insecticidal and other poisons used agriculturally or otherwise.

5. As a raw material for possible biological modification to develop products in a more usable form.

6. As a source of adhesives or binding materials which may be used in connection with felting or other procedures to provide low-cost membranes for insulation, road covering, canal lining, etc.

7. As a material for animal bedding, poultry litter, and similar uses.

8. As a raw material for packaging materials, as cleaning, scouring and polishing compounds, as absorbents for solvents used in cleaning furs, as filtering materials, and as mechanical carriers for mold or bacterial growth in zymological processes.

COTTON FIBER

The importance and urgency of a research program on cotton fiber cannot be overemphasized. Cotton is the greatest cash crop of the United States and is the most important export crop. Its production provides a livelihood to more people than does any other plant crop. During the last 10 years the cash income from cotton and cottonseed in the principal cotton-growing States has accounted for about one-half of the total cash income from all crops and livestock combined. Yet the cotton-growing industry of the United States today is facing not an expanding nor even a static market, but one which has declined seriously within the past few years and shows definite tendencies toward a further decline.

From 1920 to 1929 cash income from cotton and cottonseed averaged 1.4 billion dollars per year, but since 1929 the average (exclusive of Government payments) has been slightly less than 700 million dollars and has not risen again above the billion-dollar mark.

Undoubtedly lint cotton presents the most acute large-scale surplus problem in our country today. Even in the face of acreage-reduction programs, surpluses have been accumulating with recurring frequency. The carry-over from last year's crop, together with the comparatively small 1938 crop, gives a world supply of United States cotton between two and a quarter and two and a half times as large as the season's probable consumption.

This, in brief, is the situation now facing the cotton-growing industry of the United States. Many remedies have been proposed and some are now being applied. One important line of attack, which has until now received only minor attention from a monetary standpoint, is by means of research; not simply research on specific problems as they arise, but a comprehensive, concerted, closely knit program of research—biological, chemical, physical, technological, engineering, and economic—all carried on with the specific aim of finding new and extended uses for cotton. This is a method which should be more and more productive of worth-while results with the passing of each year. In the case of cotton, such a program is long overdue.

The regional laboratory program as herein outlined will be closely correlated with present research to prevent duplication and to assure complete and effective coverage of the very wide field remaining to be investigated. A great deal of the section on Cellulose, part III, has a direct bearing on this program and should be read in connection therewith. The program on cotton fiber has been divided into three sections—cotton lint, cotton linters, and whole cotton.

PROPOSED RESEARCH PROGRAM

Cotton Lint

Production and ginning.

1. This work will be carried on cooperatively with these existing departmental and State agencies that have adequate facilities for carrying on this work. The industrial utilization of cotton lint thus will be studied as it may be affected by varietal, cultural, and environmental differences; by variations in the machinery and methods of harvesting, ginning, storage, etc.; and by the effects of diseases, insects, and other pests. When new uses for lint develop, research toward producing cotton of improved suitability for these purposes will be inaugurated through cooperation with the production agencies.

Fundamental properties of cotton fibers.

2. This program will follow the lines indicated in the section on Cellulose, part III, but will apply specifically to cotton. It will include an analysis of the causes of differences in the biological and physical properties of cotton fiber from various sources, corresponding to differences in variety, location, season, culture, and other factors; a study of the dependence of these properties upon the molecular and micellar structure of the fiber and the influence of fiber properties upon processing and properties of cotton products.

The results of the program will serve as a guide in studying the design and improvement of processing machinery and in the development of new and improved yarns, fabrics, finishes, and treatments.

An important part of this research will be the determination of the characteristics which cause certain imported cottons and other fibers to be preferred regardless of cost for certain uses (as Egyptian types of long staple in the manufacture of sewing thread and Chinese cotton in blankets), and an attempt will be made to substitute United States cotton by a combination of agronomic, processing, and finishing research. The investigations will be correlated with those already carried on by the Department to avoid duplication of work now being adequately prosecuted and to insure the most promising and effective research attack on the problems.

Processing machinery and methods of manufacture.

3. The processing machinery and methods from bale opening to finishing textile fabrics will be investigated for possible improvement. Engineering and other research will be carried on to improve present machinery and methods, to design new machinery, and to develop new methods for processing cotton lint, in an effort to lower the cost of manufacture and to improve the quality of the manufactured product. Since the choice of industrial textile fabrics is frequently made almost wholly on a cost basis and since the price differential is frequently only a fraction of a cent, even a slight drop in the cost of manufacture would enable cotton fabrics to replace many of those made from lower-priced imported fibers.

Yarn and fabric development.

4. New outlets for cotton in the yarn and fabric field will be studied by determining the properties and cost requirements of the most promising specific uses. Research will be initiated to develop yarns and fabrics which will meet these requirements, as well as to improve the quality and lower the cost of yarns and fabrics already in use.

Work closely related to this type of research will be inaugurated toward the design and adaptation of articles composed wholly or in part of cotton fabrics, which do not necessarily involve the development of an entirely new type of fabric. Cooperation in this research will be sought and developed as deemed practicable.

Research will be conducted on the development of fabrics made from cotton mixed with one or more other fibers, for the purpose of finding certain characteristics not obtainable in fabrics made from cotton alone. Studies will also be made of the possibility of manufacturing cheaper cotton fabrics without first spinning the cotton into yarn, for instance, by binding the fibers together with some low-cost adhesive. Fabrics for both clothing and household uses will be studied but special attention will be given to industrial fabrics because this is the field which presents the greatest opportunities.

Research on finishes and treatments for cotton textiles.

5. Research of this nature will be aimed primarily toward increasing the utility of manufactured cotton products and thereby enhancing their competitive value. This type of work is especially significant from a competitive standpoint, because of the comparatively low price of cotton fabrics. For example, work will be done on finishes to render cotton yarns and fabrics more resistant to fire, mildew, crushing, creasing, soiling, abrasion, and chemical action. Research will also be undertaken on a cheaper process for permanently shrinking cotton fabrics. Cheaper and more effective treatments for water-proofing various types of cotton fabrics will be studied. Research will be done on finishes to enhance the sheen, hand, and draping properties of cotton fabrics. This last group of properties is of special importance in clothing and household fabrics where cotton has been decreasing in popularity. The development of new and improved finishes especially adapted to cotton textiles is a fertile field for research, in which only a comparatively small amount of work has been done.

Testing and evaluation of results obtained.

6. An important part of any efficient research program is the testing and evaluation of the results obtained. Except in those instances where it is clearly evident that this can be done more economically and more efficiently by other agencies, such work will be conducted by the regional research laboratories. In addition to instrumental tests under controlled laboratory conditions, actual service tests will be made for the purpose of collecting data on the behaviour of various products under actual commercial conditions and of demonstrating their practicability through appropriate channels.

Economic research.

7. An integral and highly important part of the applied research program on cotton fiber will be the collection and constant use of many different types of economic and statistical information. Such information will be helpful in selecting the most worth-while projects on which to work, will provide many clues to directions along which new research might profitably be undertaken, and will be used as an aid in the evaluation of the industrial possibilities of the products of research as they are developed.

COTTON LINTERS

While cotton linters constitute only a relatively small portion of the total fiber, their field of utility differs a great deal from that of lint cotton and it has become of sufficient industrial importance to deserve a separate program of research.

Research on chemical cotton and its preparation.

1. A close study of methods of production, purification, and storage will be made to discover means of improving the quality and uniformity of the product. For certain special purposes this is already being done by the manufacturers of chemical cotton and, where possible, a cooperative program will be arranged. The information obtained in the section on Cellulose, part III, will be of great assistance here.

2. Improvements in the preparation of the important chemical derivatives of linters will be studied, insofar as such a program is not a duplication of present industrial research. The problem of developing new derivatives with special properties will be vigorously attacked. See also the section on Cellulose, part III.

Research on uses of raw linters.

3. The use of linters in bulk as an absorbent or insulating material will be investigated. For example, a cheap proofing treatment against inflammability and microbiological attack will be sought. An analysis of the properties which are desirable will be followed by experiments for improving these properties.

4. Studies will be made also of those properties which determine the utility of competing materials and of the possibility of economically imparting some of these properties to cotton linters.

Hull fiber.

5. At present, a certain percentage of fiber remains attached to the seed hull after the delinting process and only a small percentage of this residual fiber is now utilized. The properties of this fiber will

be studied as outlined in the section on Cellulose, part III. If it shows promise, efforts will be made to work out methods and machinery for its recovery and utilization of the residual hulls, which will result in lower net costs of recovering hull fibers. In this connection, see also the section on Agricultural Wastes, part III.

WHOLE COTTON

Experiments on the utilization of the entire cotton plant as a source of industrial cellulose have so far been carried out only on a small laboratory scale with limited funds. Sufficient work will be undertaken first to determine definitely what are the possibilities of this potential source of commercial cellulose. If the results of this preliminary work indicate that further research is desirable, work will then be done on finding the most efficient pulping methods of converting whole cotton plants into industrial cellulose. Parallel to the research on pulping methods, would be genetic and agronomic work, in cooperation with related research of the Department and State experiment stations, on the selection and breeding of the most suitable varieties of cotton plants for the purpose, and the determination of the best practices with regard to spacing of rows and individual plants. Methods of recovering oil and other byproducts will also be studied, correlating the work with that on Vegetable Oils and Fats and on Agricultural Wastes, part III.

CELLULOSE

Cellulose is a major constituent of almost every plant crop. The cell walls are formed of cellulose and it constitutes about 50 percent of the solid material of most plants. It is largely responsible for the physical and chemical properties of such important vegetable fibers as cotton and wood pulp. In the last 25 years, this country has produced about 8 to nearly 19 million bales of cotton lint and about 1 million bales of linters, all nearly pure cellulose. In 1935, about 5 million tons of wood pulp (from 60 to more than 90 percent cellulose, according to grade) and about 10.5 million tons of paper and paper board (from 60 to nearly 100 percent cellulose, according to the kind of paper) were produced domestically. The enormous quantities of agricultural wastes produced annually (170 million tons, about half of which is available) also contain large quantities of cellulose.

As a specific example, considerable work has been done with the residual bagasse from sugarcane (2.5 million tons estimated as available in 1937 in the United States and possessions, which would yield about 700,000 tons of pulp of 90 percent cellulose content). Other materials in common use which consist almost entirely of cellulose or its derivatives are rayon, nitrocellulose (smokeless powder, celluloid, and lacquers), and cellulose acetate (widely used in plastics and transparent films).

These facts and figures make it plain that it is highly desirable to devote a large part of the program of the new laboratories to the enlargement of our knowledge of the properties of this important material. The more thoroughly we understand the nature of pure cellulose, the greater will be our success in properly utilizing cotton, wood, flax, agricultural wastes, and other cellulosic materials. The following program of cellulose research will of necessity require close coor-

dination with the programs on the individual commodities and cooperation with other research agencies. The following program is fundamental in nature, has a very direct bearing on the utilization of cotton, and obviously is closely related to the cotton-fiber program.

The departmental survey of current research activities has indicated present lines of activity and the proposed program will be carefully coordinated with that of other groups.

PROPOSED RESEARCH PROGRAM

Relationships between various types of cellulose.

Like other materials of biological origin, the cellulosic fibers have a distinct structural organization of both cellulosic and noncellulosic constituents. Besides this, the cellulose molecules themselves are regularly arranged in small units called micelles. Small changes in the molecule owing to its size do not modify properties sufficiently to allow separation by present methods, and the term cellulose refers actually to a group of very closely related compounds. The first problem, therefore, for a comprehensive program of fundamental research on cellulose should deal with the differences between cellulose from various sources.

1. A comparison of the different plant fibers from which cellulose is obtained will be made as to the nature and quantity of cellulosic and noncellulosic materials, the structural arrangement of these, the nature of the binding forces, and the differences in physical properties and their causes. Methods will be worked out for the separation of cellulose with as little change as possible. For purposes of comparison, either a standard method or a standard cellulosic material must be chosen, although different methods probably will be found suitable for different fibers. After removal of the noncellulosic portion, possible differences in the arrangement of molecule and micelle within the cellulosic portion will be determined. Finally, the materials must be examined for differences within the cellulose molecule, such as length, uniformity with respect to length, and nature of the end group. In this program, it will be necessary to make a careful study of the details and meaning of the present analytical methods and to devise new methods.

2. Differences in structure and composition between various parts of the same plant and various individuals of the same species, as well as changes produced by varying the conditions of growth, will be determined. These results will be of direct value in choosing the correct source of cellulose for a given use and in outlining programs for improving the plant material, separation, purification, utilization, and standardization.

Physicochemical studies on micellar and fiber structures.

3. The physical and biological properties of the fiber as an entity will be studied and analyzed. An integral part of this analysis will be a correlation of physical properties with the molecular and micellar structure, on the one hand, and with the factors governing utility, such as spinning value and the like, on the other. The orientation of molecules in and around the micelle and the position of hydroxyl and glucose groupings within the micelle will be further studied. The mechanism of phenomena and processes connected with micellar structure, such as absorption, adsorption, swelling, and diffusion, will be

more thoroughly investigated. The properties involved here have a direct bearing on certain industrial processes and products (mercerization, waterproofing, hydration of pulp, and use as a filler for plastics), and the underlying principles will be studied in collaboration with the agencies more directly interested.

Colloidal chemistry of cellulose dispersions.

4. Industrial applications frequently use cellulose solutions or dispersions. Agreement as to the nature of these has not been reached. The question as to the ultimate unit, molecule or micelle, is very important and our present data need extension in several directions. This project will include investigations of any phenomena connected with cellulose dispersions and the nature and size of the cellulose unit involved. It is of the utmost importance in connection with the processes involving the regeneration of cellulose (rayon and transparent sheets) or such chemical reactions as acetylation.

5. Standard materials and methods will be developed. Different workers have characterized their materials in different ways and have used widely divergent concentrations and formulations in preparing dispersions. Much important work, in which well-characterized cellulose or standard cuprammonium dispersions were not used, should be repeated. It is believed that this will explain and correct many discrepancies.

6. Viscosity and ultracentrifugal methods will be compared in the development of an industrial standard and as a means of measuring molecular size. Certain anomalies in the properties of dispersed cellulose at higher concentrations and in different solvents are still to be satisfactorily explained. Of great help in this problem will be the comparison of solutions by these two methods.

7. The relation between orientation of cellulose or cellulose derivatives in dispersion and the properties of such dispersions or of cellulose regenerated therefrom will be determined. Optical methods are of particular importance, and the use of substituents containing heavy atoms will facilitate spectroscopic investigations.

Chemical reactions.

8. This project will include a study of the processes involved in the preparation of derivatives from cellulose and a determination of the constitution and properties of these derivatives. The effect of chemical structure on physical properties, such as tensile strength, elongation, flexibility, and heat resistance, will be studied with a view toward preparing derivatives of any desired properties. The types of reaction studied will include hydrolysis and depolymerization, oxidation, etherification, esterification, etc. The relative rates of reactivity of various parts of the molecule and fiber will be studied, to properly carry out and control important reactions. The applied phases of these studies are treated in the section on Cotton Fiber, part III.

Microbiological studies.

9. These will include two types of investigation, the study of the attack by common micro-organisms with the aim of preventing damage therefrom, and exploratory work on cellulose fermentations to determine the possibility of utilizing cellulose in this manner analogously to starch. (See Fermentation, pt. III.)

COTTONSEED

A brief review of the economic status of cottonseed products is given in part II. There it is pointed out that cottonseed oil is the most important vegetable oil consumed in the United States and that it, along with cottonseed meal and hulls, has returned to the growers in the last 2 years 141 and 131 million dollars, respectively; and during more prosperous times, approximately 200 million dollars annually. About 90 percent of the factory consumption of cottonseed oil is for edible purposes, and cottonseed meal is used almost entirely for feed and fertilizers. The hulls are used chiefly for feed. Thus it is evident that cottonseed products are already being used extensively in industrial and other outlets.

Unless present varieties are modified by agronomic research, the amount of oil and meal produced will be governed by the production of lint. Since imports of vegetable oils have exceeded a billion pounds in recent years, it is evident that a very extensive market already exists, which after research for specific adaptation to outlets now being filled by these imported oils, probably could be filled to a considerable extent by cottonseed oil. (See *Oil Seeds and Crops*, pt. II.) These factors point definitely to the desirability of emphasis on research to increase the ratio of oil content to fiber content of the cotton plant.

Further emphasis should be placed on fundamental studies to find new uses for cottonseed proteins, such as in the preparation of amino acids, utilization in plastics and in emulsions, etc. Successful consummation of this work would be very beneficial in that it would add value to the total cotton crop, thereby absorbing more of the cost of producing the crop, and placing domestic cotton fiber in a better competitive position with that produced in foreign countries.

In the outline of proposed research that follows a comprehensive program is visualized. Some features are now under active prosecution by Federal, State, and other agencies. The proposed program will be fully correlated with all current research and no lines of work now being adequately followed will be duplicated. Because emphasis has been laid previously upon the desirability of increased oil content of the plant and upon new uses for the protein, it should not be felt that the other portions of the program are unimportant. The other sections are vital to a well-rounded effort and have their proper place. Certain portions of the work on cottonseed will be found in other sections of part III as follows: Proposed studies on cottonseed oil which have a broad application to all oils and fats will be found in the section on Vegetable Oils and Fats; proposed studies on cottonseed protein of a broad general nature will be found in the section on Proteins; proposed studies on cottonseed hulls will be found in the section on Agricultural Wastes.

PROPOSED RESEARCH PROGRAM

Work on the following subjects will be undertaken:

Agricultural.

1. In cooperation with related research of the Department and State stations, research as to the effect of genetic, varietal, environmental, sectional, and economic factors on the ratio of fiber to seed, on the ease of separation of fiber and seed, and on the yield, quality,

and cost of producing oil, proteins, and other seed components; the effect of temperature, moisture content, and respiration during storage, on the quality and yield of linters, oil, proteins, and other components.

Processing.

2. Engineering and other studies to improve machinery and processes for delinting cottonseed.

3. Chemical, physical, engineering, economic, and other investigations of methods of dehulling, conditioning, cooking, pressing, extracting, and other treatments to reduce costs, improve quality, yield, or composition of oil, protein, or other component of the seed or to protect or modify advantageously the properties of any component, during or prior to the separating process.

4. Chemical, physical, engineering, and other research to improve refining, bleaching, deodorizing, hydrogenating, or other processing methods to reduce costs, improve quality, or yield of oil or fatty acids; or to remove, protect, or modify advantageously the properties of any component, or to determine the composition of, and methods for the recovery and utilization of, any component removed in these operations.

5. Chemical, physical, engineering, and other research to develop or improve processing methods applicable to or required in the production of cottonseed proteins or components of, or products made from, cottonseed proteins.

Utilization.

6. Chemical, engineering, economic, and other investigations concerning the adaptability of cottonseed oil or fatty acids or other components of the oil used as such, or hydrogenated, subjected to pyrolysis, or otherwise treated, or blended or compounded with other materials in the preparation of soaps, greases, lubricants, emulsifying agents, emulsions, penetrating oils, sizes, finishing agents, and similar or related materials used in the textile, laundry, metal goods, rubber, leather, lubrication, and other industries.

7. Chemical, engineering, and other studies designated to provide industrial outlets for the proteins and other components of cottonseed meal, either as such, or after chemical or physical modification.

Fundamental research.

8. Chemical and physical studies to determine the various fundamental characteristics, reactions, and properties of cottonseed oil, fatty acids, proteins, and other seed components, in order to provide a firm basis for research applied to new and extended uses.

9. Fundamental chemical and physical studies to improve and develop methods for the analysis of cottonseed oil, fatty acids, proteins, and other cottonseed components.

10. Fundamental chemical and physical studies on the isolation, characteristics, reactions, and properties of gossypol and other pigments, phosphatides, sterols, vitamins, and other minor components present in cottonseed, including specific fundamental work on cottonseed oil and cottonseed protein not covered under the general sections on Proteins, and Oils and Fats.

11. Fundamental chemical, physical, and engineering studies on the effects of metals and other materials of construction on the color, odor,

stability, and other chemical and physical properties and reactions of cottonseed oil, fatty acids, proteins, and other seed components.

12. Fundamental chemical and physical research on methods for the modification of cottonseed oil, fatty acids, proteins, and other seed components to provide different properties of possible industrial value.

VEGETABLE FATS AND OILS

No nation or group of people can exist without adequate supplies of oils, fats, and waxes; moreover, the more highly civilized a nation becomes the greater is its needs for these materials. Industrialized nations require not only considerable quantities of fats and oils for food uses, but also enormous quantities of these commodities as industrial raw materials, e. g., the total consumption of oils, fats, and waxes in the United States for 1937 exceeded 9 billion pounds.

Oil seeds constitute one of the most important crop groups wherever agriculture is practiced, whether by the most primitive or the most mechanized methods of cultivation. The processing of oil seeds is also an important part of any economic system, however diversified, since considerable labor is employed and many commercial materials are produced. In highly industrialized countries, the investment in processing plants and equipment is very large and, together with consuming industries depending almost exclusively on the oil seeds for their raw materials, the capital investment amounts to many billions of dollars. Many different kinds of oleaginous materials that are consumed in a multitude of finished products ranging from shortening and salad oils to paints, linoleum, lubricants, etc., are derived from oil seeds.

Cultivation of oilseed plants, processing of the seed for oil, and utilization of oil for food and household purposes are as old as civilization. During the course of the centuries, our knowledge concerning the production and utilization of vegetable oils, also animal oils, has progressed to the extent that almost every item of commerce contains oils, fats, or waxes in one form or another. Many of our most modern industries depend, to some extent, on available supplies of these products, which in many cases originate and are controlled beyond the confines of the United States. Despite the fact that there are surplus quantities of certain of the domestic oils, huge quantities of palm oil, and the major part of the so-called drying oils are imported. The main reason for this is that methods are not yet available for converting surplus domestic oils to products suitable for the soap and paint industries.

Adaptation of oils for industrial purposes has followed in some cases as a result of increased knowledge of the properties of oils, and in other cases by following empirical or trial-and-error methods of formulation. Further technological advances in the utilization of fats and oils are becoming increasingly difficult owing to lack of fundamental information concerning their physical and chemical properties.

A program designed to increase our knowledge of the fundamental physical and chemical properties, to improve present technological practices, to produce drying and soap oils from surplus domestic oils, and to explore the possibilities of new industrial outlets for fats, oils, and waxes, follows.

PROPOSED RESEARCH PROGRAM

Glyceride fraction.

1. A vital part of any thorough search for new and extended uses must be a fundamental study of oils and fats with respect to the composition and structure of the various glyceride molecules; their synthesis, degradation, and rearrangement from the structural viewpoint; their chemical and physical stability; the physical properties of the pure glycerides and their mixtures in various proportions; the preparation and purification of the component fatty acids; the chemical and physical properties of the purified fatty acids and derived materials.

Nonglyceride fraction.

2. Investigations should be undertaken on the isolation, identification, and industrial application of the pro- and anti-oxidants, sterols, phosphatides, vitamins, hydrocarbons, ketones, alcohols, and such other minor components as may be detected in various oils, fats, and waxes. The naturally occurring crude oils contain many substances which have been inadequately studied and in many instances have never been isolated and characterized. A few of these minor components are known to be of value and use either per se or as raw materials for the preparation of other products.

Odor.

3. Often crude oils contain materials which impart characteristic odors and refined oils are subject to the development of secondary odors. Substances producing these odors have not been isolated and identified and hence practically nothing is known of their chemical and physical properties. Their removal, however, is necessary to render the oils useful for technological as well as edible purposes. Studies should therefore be made of the various oils and fats with the object of isolating and identifying the products responsible for the characteristic odors of crude oils; removing odors by most effective and economic methods; determining the nature and mechanism of the development of reversion and rancidity in refining oils; preventing or inhibiting reversion and rancidity.

Color and bleaching.

4. Like odor, it is essential that pigments be removed in the refining process to enhance the value of oils for certain technological uses. A major project with reference to color should have for its objectives an investigation of the nature and amounts of pigments present in crude and refined oils; the development of methods for their rapid detection and evaluation; the study of the effect of processing and bleaching agents on the natural pigments; the determination of the mechanism of yellowing and other discolorations of finished products.

Physical properties.

5. To facilitate the development of extended technological uses of oils and fats, the physical constants and properties of those products should be determined. Measurement of these properties should be made with the highest precision, over the widest possible ranges of temperature and pressure. Examples of physical properties to be measured are the viscosity, thermal conductivity, and dielectric constants.

Chemical properties.

6. Investigations, especially with a view to development of new materials for commerce and industry, are dependent on chemical and physical alteration of fats and oils. The effect of chemical reagents on oils and fats should be completely investigated. Such studies should include the migration of double bonds; the enhancement of unsaturation; the addition of various elements and compounds to the double bonds; the modification of the carboxyl group; the rupture of linkages to produce products of shorter chain length than those in the original oil; the effect of heat over a wide range of temperatures, especially in the region where cracking ensues.

Processing.

7. Laboratory and semiplant studies should be carried out on the various processes for separation of the oil from the seed; for refinement or purification of the oil; and for the separation of the fatty acids and esters derived from the natural products.

8. Investigations should be made dealing with the development of methods for converting the domestic nondrying oils to drying oils. Studies in this field should also include mechanism of film formation, oxidation, and polymerization, plasticization reactions as well as practical problems on formulation, production, and testing of derived products.

Nonedible oils.

9. Problems pertaining to the industrial utilization of oils, fats, and waxes for the production of soaps, wetting agents, dry-cleaning fluids, etc., are in need of investigation. Of considerable importance to the domestic oil and fat industry is the possibility of adapting domestic oils to the processes in which imported oils are now used, such as olive oil in the textile industry, palm oil in the soap, tin, and terneplate industry, and sperm oil in the leather industry.

PEANUTS

In part II there is included a brief review of the economic status of peanuts. In spite of increased production of peanut oil during the past few years because of greatly increased crushings, imports of approximately 50 million pounds were made in the 12 months ending September 30, 1937.

An extensive domestic market for vegetable oils is now being filled to a considerable extent by imported oils, but research directed toward specific adaptation to these requirements may open up a large new outlet for peanut oil.

Average production of peanuts has varied between 610 and 802 pounds per acre for the years 1916 to 1937. At this rate of production the price per pound necessary to insure an attractive return to the grower does not usually permit peanut oil to be produced so that it can compete advantageously with imported oils. It is apparent therefore that the most vitally needed research on peanuts is that which will increase the yields of nuts per acre or reduce the cost of production to such an extent as to provide a satisfactory net return to the farmer and to permit successful competition with imported oils.

The proteins of peanut meal are more readily obtainable in an unaltered condition than those from cottonseed, because of the absence of such severe processing as takes place when cottonseed is cooked prior to pressing. If care is used in the selection of nuts for pressing there should then be available in the meal an excellent raw material suitable for the production of new and interesting proteins and other products of industrial value and capable of extending the uses of peanuts into new industrial fields.

In the outline of proposed research that follows there will be found, besides the agronomic and protein work stressed above, other sections of vital importance to the whole study. Some of the features of the following program are now under active prosecution by Federal, State, and other agencies. The proposed program will be fully correlated with all current research and no lines of work now being adequately pursued will be duplicated.

PROPOSED RESEARCH PROGRAM

The following types of research are proposed:

Agricultural.

1. In cooperation with related production research of the Department and State agricultural experiment stations, genetic, cultural, varietal, and other investigations to improve peanut varieties, increase yields, and decrease costs per acre and to widen their regional adaptation and place in crop rotation and in the agricultural economics of the South.

Processing.

2. With the objective of new and extended uses, chemical, physical engineering, economic, and other investigations of methods of hulling, blanching, pressing, extracting, and other treatments before or after pressing and extracting to reduce costs, improve quality, yield, or composition of oil, protein, or other peanut components, or to protect or modify advantageously the properties of any component, during or prior to the pressing or extracting process.

3. Chemical, physical, engineering, and other research to improve refining, bleaching, deodorizing, hydrogenating, or other processing methods; to reduce costs, improve quality or yield of oil, or to remove, protect, or modify advantageously the properties of any component; or to determine the composition of, and methods for, the recovery and utilization of any component removed in these operations.

4. Chemical, physical, engineering, and other research to develop or improve processing methods applicable to or required in the production of peanut proteins, or components of or products made from, peanut proteins.

Utilization.

5. Chemical, physical, engineering, economic, and other research to develop new industrial uses specifically for peanut oil, fatty acids, proteins, hulls, and other products and components.

Fundamental.

6. Chemical, physical, and other research to develop methods for the analysis of peanut oil, fatty acids, proteins, and other peanut products and components.

7. Chemical and physical studies to determine the various fundamental characteristics, reactions, and properties of peanut oil, fatty acids, proteins, and other peanut components. (See sections on Proteins and Vegetable Fats and Oils, pt. III.)

8. Fundamental chemical and physical studies on the isolation, characteristics, reactions, and properties of phosphatides, sterols, vitamins, pigments, and other minor components of peanuts.

9. Fundamental chemical, physical, and engineering studies on the effects of metals and other materials of construction on the color, odor, stability, and other chemical and physical properties and reactions of peanut oil, fatty acids, proteins, and other peanut components.

10. Fundamental chemical and physical research on methods for the modification of peanut oil, fatty acids, proteins, and other peanut components to provide different properties of possible industrial value.

APPLES

In part II the current domestic apple situation is considered in some detail as well as the changes which have taken place during recent years in regard to various phases of apple production, export trade, increased competition of other fruits, etc. There it is pointed out that over a long period of years total apple production has decreased only slightly, although the number of bearing apple trees has decreased tremendously. This trend suggests that the average annual production during coming years is not likely to increase, but instead may show some decrease.

Increased competition from other fresh fruits, particularly the citrus fruits, the large loss of our apple export trade, which has been felt especially by the apple growers in the Pacific Northwest, and other economic factors, have been largely responsible for the accumulation of large surpluses of marketable apples and unsatisfactory price conditions, which have prevailed during good production years. In addition to large surpluses of first-grade apples enormous quantities of culls accumulate annually, for which new profitable uses are urgently needed. Approximately 20 percent of the total apple crop is used in the preparation of apple products such as cider, vinegar, canned apple sauce, etc.; and in these processing plants large amounts of pomace, seeds, and other byproducts occur which are largely wasted. At present, apples find no industrial uses.

As a raw material for preparation of products for other than food or beverage uses, the apple is relatively expensive since it consists of over 85 percent water. Transportation costs to processing plants therefore represent an important item of expense for any method of utilization. In the case of cull fruit, which is sorted out at the packing plants, and the byproduct materials available at processing plants, transportation costs are borne entirely by the present salable products. For the utilization of surplus fruit, however, which in many instances is not harvested, it will be necessary to find such profitable uses as will carry the entire cost of production, collection, transportation, and processing. For these and other reasons it becomes apparent that the development of profitable industrial outlets for apples probably in the main will be confined to surplus fruit in areas of heavy production, to cull apples, and to the pomace available in processing plants.

In considering new uses for the apple the composition of the apple is of chief importance. The dry matter of this crop consists chiefly of fermentable sugars and pectin, with minor amounts of cuticle wax, protein, fat, fiber, malic acid, and mineral constituents. Of these constituents pectin and cuticle wax offer the greatest promise in development of nonfood uses. The diversion of apples into industrial channels for applications dependent on the other components presents an admittedly difficult problem.

A program of research to serve as a basis for the industrial utilization of apples will be most effectively pursued by close coordination with economic surveys and analyses.

PROPOSED RESEARCH PROGRAM

Fundamental.

1. Comprehensive physicochemical and chemical investigations to supplement our present inadequate information on the composition of apples of different varieties at different stages of ripening will be conducted. The more complete information concerning the individual apple constituents thus made available will be of fundamental importance in determining the possible new uses which may be developed.

Storage and dehydration.

2. Problems on storage, preservation, and water removal encountered in processing apples will be attacked. This type of research will be dependent on the processing operations to which apples are to be subjected and the uses developed for apples or their products. Current knowledge evolving from food research on apples will aid in the orientation of work in this field.

Pectin.

3. Methods will be refined or developed for the preparation of pectin from apples. Apple pomace, the waste from processing plants, contains 15 to 18 percent pectin and is a particularly promising source of material. The chemical and physical properties of apple pectin will be determined, and the results will be applied to develop new or to expand old uses for this product. (For additional details, see section on Pectin, pt. III.)

4. Laboratory studies will be made on the separation of the waxy coating of apples from whole apples, apple skins, or pomace. Particular emphasis will be placed on methods permitting the consecutive preparation of cuticle wax and pectin. The constituents of the wax will be separated, determined, and their chemical properties elucidated. Industrial uses for the wax itself or the components will be investigated. Of special significance is the constituent ursolic acid which may provide an economical source of raw material for the synthesis of such pharmaceuticals as the sex hormones.

Other components.

5. Investigations will be conducted on constituents such as sugars, pectins, fats, acids, etc. Their preparation will be considered and their possible uses weighed.

Fermentation.

6. Microbiological studies on processed apples designed to produce compounds of possible industrial value will be instituted. Various molds, bacteria, or combinations of micro-organisms will be tested.

The direction this research will take will depend on the results obtained. (For further information on this phase of the program see section on Fermentation, pt. III.)

Seed products.

7. Methods will be developed for separating and collecting seeds from the flesh or expressed pulp. The oils, proteins, and other constituents will be separated and their compositions determined. The possibility of utilizing these products as industrial sources of raw material will receive attention. (For fundamental programs on related materials, see sections on Proteins and Vegetable Fats and Oils, pt. III.)

Pilot-plant operations.

8. Promising results on the laboratory scale will be transplanted to the pilot-plant basis.

Economic.

9. In addition to and correlated with the forementioned investigations, studies to determine the economic feasibility of developing nonfood uses for apples will receive attention. Such studies will include a broad economic survey of the potential and actual apple surpluses, culls available, and their geographical distribution particularly in relation to existing processing facilities, and will involve a careful evaluation of the economic possibilities in the development of new and extended industrial uses for apples as such, as well as uses for their individual constituents.

FRUITS

Peaches, grapes, pears, plums, prunes, cherries, apricots, olives, figs, and melons, which are listed in order of importance from the standpoint of farm value, are the fruits considered in this section. The economic view, production figures, and the surplus situation have been discussed in part II. There it was shown that the trend in production is toward moderate increases in the more important fruits. Annual average per capita production of 13 leading fruits increased from about 177 pounds for the 1919-23 period to 206 pounds for the past 5-year period (1934-38), this increase being consumed mainly in the form of juice.

Practically all the fruit marketed is used as food, either in the fresh, canned, or dried form, or as juice. Only insignificant amounts find industrial uses, for example, certain grape concentrates are employed for the production of tartaric acid and tartrates. Owing to the tremendous quantities of fruits processed either as canned flesh or juice, huge tonnages of refuse and byproducts are available for further uses. In addition, about 15 to 25 percent of the total crop in the form of culls is in urgent need of profitable channels. In addition to pomace wastes and culls, the following approximate amounts of the more important fruits were in surplus this season: Peaches, 800,000 tons; grapes, 700,000 tons; pears, 200,000 tons; cantaloups, 150,000 tons.

Most promising as raw materials for industrial uses, are those commodities now in surplus regularly or those constituting wastes or nuisances. In the latter class are cull or submarket grades of fresh fruits and the waste or discard portions that regularly accumulate at

centralizing points where the fresh fruits are prepared for market. Analogous materials at processing plants are fruit pits and the fibrous or pulpy wastes of fruit-juice manufacture. In most cases these materials have no value, and serious problems are introduced in attempts to dispose of them in streams or rivers.

In developing new uses for fruits or their products economic considerations and a knowledge of the composition of the various fruits are of primary importance. Fruits contain about 80 percent water and are rich in sugars, pectin, and waxes. As a whole, however, chemical information on fruit constituents is quite inadequate and must be secured to adequately evaluate the possible industrial utilization of fruits.

The proposed program, therefore, has as its first objectives the determination of a complete chemical inventory of the various surplus fruits and the evaluation of the economic aspects of their industrial utilization.

PROPOSED RESEARCH PROGRAM

Agricultural.

1. Studies will be made, in cooperation with related production research of the Department and State agricultural experiment stations on the effect of environment, genetics, breeding factors and orchard management, upon the kind and amount of the chemical constituents in the fruits and their seeds. Maturity and ripening of fruits as they affect the components of fruits and seeds will receive similar attention. These studies will be coordinated with related research activities of Federal and State agencies.

Storage and processing.

2. Methods will be improved or developed for storing the hydrous or anhydrous fruit, processed fruit, or pomace as this factor relates to new uses. The physical and chemical conditions for preserving fruits in their various forms will be determined. Among the factors which will be considered are temperature, humidity, and use of gases or preservatives. Studies of this sort are necessary in the development of year-round industrial operations. The processing of fruit as related to drying, grinding, separation of the component parts of fruits, etc., will be examined.

Census of constituents.

3. A fundamental research program will be initiated to determine by physical, chemical, and biochemical techniques, the amounts and the kinds of constituents present in the different parts of the various fruits under consideration. These results will suggest which constituents, fruits, or varieties of fruits offer promise in regard to industrial uses.

Pectin.

4. Improved methods will be studied for the isolation of the various fruit pectins from fruits, culls, or processing wastes. Information will be secured on which fruits afford the most practical sources of pectin. The physical and chemical properties of these various pectins will be determined, and the results will be applied in discovering new uses for these materials. For detailed information on the program to be pursued, see Pectin, part III.

Cuticle wax.

5. Improved methods will be developed for preparing the waxes from the various deciduous and stone fruits or their processing wastes. The properties of these different waxes will be determined, and the waxes separated into their components. Physical and chemical investigations will be performed on the constituents, and their possible commercial uses will be probed. Cuticle waxes occur in relatively large amounts in the smooth-skinned fruits. Of considerable significance will be data on the quantity of ursolic and oleanolic acid present in these waxes, since the acids because of their relationship to sterols, are potential raw materials for the production of medicinals as well as other synthetic industrial compounds.

Anthocyanin pigments.

6. Grapes, grape pomace, plums, prunes, and certain varieties of cherries are rich in purple pigments which will be separated by improved or new procedures. The pigments will be resolved into the components, the physical and chemical characteristics of which will be determined. Their possible use as industrial pigments will be evaluated.

Other products.

7. Fruit sugars, acids, flavors, enzymes, etc., will receive appropriate treatment, and uses for these compounds in industrial channels will be investigated. The production from domestic crops of tartaric acid and tartrates that at present are prepared in part from imported grape concentrates will receive extensive treatment. Industrial demands for tartaric acid present an opportunity to establish a new domestic industry that will utilize grapes as a raw material.

Fermentation and composting.

8. Nonalcoholic fermentation of the various fruits or processing wastes for the preparation of acids and other special organic compounds will receive attention. Particularly worthy of investigation is the conversion of waste fruit products into artificial manures. These investigations will be conducted along lines similar to those described for the fermentation of glucose and starch in Fermentation, part III, and for the conversion of agricultural wastes to artificial fertilizers under Composts in the section on Agricultural Wastes, part III.

Pits, seeds, and shells.

9. Methods will be developed for the expression and recovery of kernel oils. Physical and chemical studies will be performed on the various oils as well as on their constituents. (For detailed program see Vegetable Fats and Oils, pt. III.) Seed or pit proteins will receive investigation in regard to preparation, determination of properties, etc. (See Proteins, pt. III.) Studies will be carried out on the isolation and characterization of the minor seed constituents such as the glycosides, alkaloids, and enzymes. Applied research will be performed on the possible industrial utilization of these materials as well as of the shells.

Pilot-plant operations.

10. Laboratory results of industrial promise secured in the foregoing investigations will be subjected to pilot-plant studies in order to evaluate further their possible commercial utilization.

Economic analyses.

11. Economic studies will be an integral part of the research developed as outlined in the preceding program. A careful survey of the distribution, availability, and amounts of raw materials will be made as well as of their component parts. Subsequent to these studies, research on the economic merit of new products or methods will be developed. Such correlation will permit the regional laboratories to give industry not only scientific and technical information concerning these developments, but they also will be able to present information relative to harvesting, processing, and manufacturing costs for industrial uses, which will facilitate industrial evaluation of the work.

CITRUS FRUITS

One of the recent and significant trends in fruit production concerns the striking increase in the output of citrus fruits. As yields vary from season to season, sufficient acreage must be maintained to care for these fluctuations and to provide for consumption needs in lean crop years. This means inevitable surpluses in years of bountiful yields. The surplus situation is expected to become more acute as young trees, planted several years ago, come into bearing. The approximate amounts ¹ on the fresh-fruit basis of citrus fruits in surplus are as follows: Oranges, 60 thousand tons; grapefruit, 120 thousand tons; and lemons, 57 thousand tons. In addition, somewhat over 100 thousand tons of citrus fruits were not harvested and had no farm value. Tremendous quantities of pomace, wastes from processing plants, are annually discarded and, therefore, available for industrial purposes.

Citrus fruits are relatively rich sources of pectin, essential oils, and citric acid. Lemon and orange peel on the dry basis contain approximately 30 percent pectin, and the yield of essential oils per ton of fruit ranges between six and twelve pounds. These products, as well as citric acid, are now manufactured from citrus fruits and find use in the food and synthetic industries. An important recent development is the large increase in our export trade of pectin. Uses have not yet been found for the seed oils and proteins, press cake, and the glycosides, hesperidin and naringin. Discovery of outlets for these products would help to bear the cost of producing pectin, citric acid, and essential oils and place the industry on a sounder competitive basis. Expanding markets for citrus products would, no doubt, result from information made available by a broad research program on citrus fruits.

In presenting the following program it is recognized that some research has already been done and other work is now in progress along lines analogous to those proposed. However, interested groups desire further expansion of these fields of work and fundamental data on the physical and chemical properties of the constituents of citrus fruits.

In formulating a sound program on the possible industrial utilization of citrus fruits, an economic inventory of citrus fruits is of first importance. The following proposed program takes these factors into consideration:

¹ U. S. Department of Agriculture Preliminary Estimates of Farm Products, Byproducts and Wastes, Available for Industrial Uses (1935).

PROPOSED RESEARCH PROGRAM

Agricultural.

1. Citrus fruits are among the most variable of all horticultural products. Variations in size, color, flavor, texture, juice content, and composition are influenced by season, climate, soil, fertilizers, root stock, and variety. For this reason, quality studies on citrus fruits and their products will be integrated with their cultural and genetic backgrounds. Cooperative studies will be arranged with existing agencies of the Department of Agriculture and the State agricultural experiment stations to perform the horticultural phases of this work.

Pectin.

2. Improved and less-expensive methods of extraction will be investigated. A fundamental study will be undertaken to secure physical and chemical data which will be applied to improve the nature of the product and to extend its uses in industry and medicine. For a detailed description of the program to be pursued, see Pectin, part III.

Citric acid.

3. Further studies designed to lower cost of production of citric acid from citrus fruits will be undertaken to meet the competition of fermentation citric acid. Although citric acid and citrates have been commercial products for many years, their possibilities as sources for synthetic chemicals have not been thoroughly exploited. A study of this type will form a basis for further industrial development of citric acid.

Essential oils.

4. Use of the essential oils of citrus fruits for flavoring and medicinal purposes dates back to early history, but methods of production still need to be explored. A study will be made to improve the quality of the products and to reduce the cost of production. These oils consist chiefly of terpenes. If terpenes can be recovered from waste citrus peel at a low-enough cost, they may find a market in the lacquer and synthetic industry along with the dipentene fraction of wood turpentine. The deterpenated oils already are used to some extent as flavoring agents for beverages and other food products. Studies directed toward reduction of production costs and the development of methods of preservation will receive attention.

Glycosides.

5. Citrus fruits contain the characteristic glycosides—naringin, hesperidin, and "citrin." Investigations will be instituted to determine their pharmacological, physical, and chemical properties. The industrial utilization of these glycosides and their use as sources for rare sugars and flavanones will be investigated.

Other byproducts.

6. In addition to the citrus components previously mentioned the fibers, sugars, vitamins, etc., present in citrus fruits will receive attention both from a fundamental and an applied point of view.

Seed products.

7. Enormous volumes of seed accumulate at citrus fruit-canning plants and this material offers an important source of oils, fats, proteins, etc. Methods will be developed for isolating these products and characterizing them and studies will be made to determine their

possible commercial utilization. For further information on this program, see sections on Proteins and Vegetable Fats and Oils, part III.

Peel, rag, and processing wastes.

8. Citrus wastes are already serving as a humus and fertilizing material and are being returned to the soil in liberal quantities. Further investigations will be performed relative to the composting of these wastes. For a detailed program, see Composts in the section on Agricultural Wastes, part III.

Microbiological studies.

9. Studies will be made on the effects of different organisms and of different strains of the same organisms on citrus wastes, cull fruits, and rag under controlled conditions of air, temperature, and humidity, with the aim of developing products of industrial value. For further details, see Fermentation, part III.

Economic studies.

10. Economic studies will be an integral part of the research program. A careful economic survey of the potential and actual surpluses and culls available from citrus fruits will be of primary importance for an industrial program. These findings will be more truly evaluated when considered in relation to the amounts and kinds of constituents found available for possible industrial utilization. The economic merit of any research developments on new methods, or new products will be determined.

PECTIN

Pectin constitutes a considerable portion of the middle lamella, the material which binds the cellulose walls of plant cells together. The softer plant tissues, such as fruits and certain vegetables, have as a rule much higher percentages of pectin than woody tissues. Among the principal sources of pectin are apples, oranges, lemons, and grapefruit; also apple pomace and citrus pulps left after the commercial extraction of fruit juices; and beet pulp, a byproduct in the manufacture of beet sugar. The pectin content of some of these materials on a dry basis is estimated as follows: Apple pomace, 15-18 percent; lemon pulp, 30-35 percent; orange pulp, 30-40 percent; beet pulp, 25-30 percent; carrots, 7-8 percent.

Although the chemistry of pectin, which seems to be a complex carbohydrate derivative of high molecular weight containing arabinose, galactose, and galacturonic acid units, is still not very well understood, considerable progress has been made in the industrial utilization of pectin. Production and exports of pectin have increased strikingly in recent years.

Two outstanding physical properties, gel formation and adhesion, are responsible for the great commercial importance of pectin. Wide use of this material has been made in the manufacture of jellies, jams, and marmalades; as a stabilizer for tomato juice and catsup; as an emulsifying agent in the baking and confection industries; and in salad dressings. Pharmaceutically it is used in the manufacture of emulsions of castor-oil and mineral-oil laxatives. Further it is employed as a powder alone or mixed with kaolin for the treatment of dysentery, this use being based on the discovery that pectin inhibits

the growth of many intestinal pathogens. Many other uses are being evaluated such as in the preparation of tree-spray emulsions, the manufacture of mucilage, and as a blood agglutinant in dressing wounds.

To afford a firm foundation for the further industrialization of pectin, a broad program emphasizing the fundamental study of pectin is proposed. This, together with applied studies, is outlined below.

PROPOSED RESEARCH PROGRAM

Agronomic.

1. In cooperation with the State agricultural experiment stations and other Federal agencies, this research will include the study of the effect of variety, location, cultural conditions, etc., on the yield and quality of pectin from various sources.

Preparation.

2. Studies will be made on the drying and storage of fruits, vegetables, pomace, and pulp, in relation to pectin and its extraction, and investigations will be conducted on the development of improved and cheaper methods of extracting pectin.

Physical properties.

3. The physical and colloidal properties of pectin and its gels and emulsions will be determined. Pectin from various sources will be employed and the reasons for differences investigated. Modifications of these properties by chemical reaction or by the addition of electrolytes or nonelectrolytes to gels and emulsions will also be examined.

Chemical properties.

4. The preparation and properties of chemical derivatives will be investigated and an attack made on the problem of the molecular constitution of pectin. Enzyme action and both alkaline and acid hydrolysis may be valuable.

Pilot-plant operations.

5. This work will include all problems arising from the transfer of production processes from a laboratory scale to a semicommercial or commercial basis and will be aimed toward lowering costs and improving the quality of the product.

Utilization.

6. Attempts will be made both to increase present uses and to find new uses for pectin, mold pectinase, and related substances. Further study will be made of the use of pectin as a stabilizing and emulsifying agent, as in pharmaceutical and spray emulsions, and in the control of fermentations, etc.

VEGETABLES

A general review of the production, disposal, and economics of the vegetable crops of the United States has been given in part II. A picture of the relative importance of vegetables and of the problem of their utilization may be gained by reading that section of the report.

Vegetables may be used as fresh products and in canned, dried, or other processed form as food; in crude or processed form as feeds, including much material otherwise wasted from fresh or cannery uses; and for industrial specialties other than food or feed, usually as cull

material, surplus goods, or parts discarded during processed food manufacture.

New uses of vegetables must be planned to fit in with one or more of the present main channels of crop disposal. The coordination of new activities with those already under way must take account of the availability of desired materials in adequate quantities, possible competition with present business, and the secondary effects on present agricultural practice of any new activity that develops.

These commodities now in surplus regularly or constituting wastes or nuisances of present business are the most promising raw materials for investigation. They comprise, in the main, cull or submarket grades of fresh vegetables, and the waste or discarded portions such as celery and lettuce trimmings that accumulate regularly at centralizing points where the fresh foods are prepared for market. Other materials which accumulate at processing plants include asparagus butts, pea pods, vines, and like substances. In most cases these wastes are already serious problems, because they constitute actual nuisances that require early attention to prevent danger to water supplies or public health and comfort.

However, it must be borne in mind that production of the commodities which contribute to the waste supply is seasonal and that, therefore, the wastes accumulate during relatively short periods of time. This means that, if they are to be used for industrial manufacturing purposes, they must be so processed initially as to furnish the continuous source of supply necessary to support such utilization.

It should also be pointed out that in any program dealing with the development of industrial uses for vegetable material the fact that these materials are produced in widely scattered areas of the country must be considered. Moreover, many of them are of highly perishable nature, which is a serious obstacle to overcome in the development of a program for their utilization; but perhaps the most serious handicap in the development of uses for these commodities is their low content of constituents now having industrial value. Furthermore, present knowledge of the chemistry of many of these constituents is inadequate, which fact makes more difficult the problem of their isolation and characterization.

For these reasons, vegetables as a whole have received relatively little attention from research groups that ordinarily might be expected already to have developed programs dealing with wider industrial uses for them.

In formulating a sound program on the possible industrial utilization of vegetables, economic studies and a chemical inventory of vegetables are of first importance.

PROPOSED RESEARCH PROGRAM

The following lines of research will be undertaken:

Agricultural.

1. In cooperation with State agricultural experiment stations and other Federal agencies, the effect of nutrient and climatic conditions and varietal changes on the kind and amounts of various chemical constituents produced in the roots, stalks, leaves, and seeds of vegetables. Certain physiological disturbances of plants, for instance, have been found to be caused by an inadequate supply of some minor

element and such disturbances may seriously affect the quality of the commodity. Studies of this sort offer a logical attack on the problems dealing with the development of cheaper, yet better balanced commodities, and they may point the way toward the development of types of vegetable products which will be particularly rich in some special constituent suitable for industrial utilization.

Census of constituents.

2. A complete inventory of the constituents occurring in the vegetables will be made. For such an inventory a compilation from the scientific literature of all recorded data pertaining to these commodities is necessary. Work of this type may be begun during the construction of the laboratory buildings. This information will be supplemented by data obtained from analyses of vegetable components and quantitative determinations of their physical constants. Knowledge made available by these studies will aid in evaluating the possible industrial uses for the different vegetables.

Storage and processing.

3. Economic methods for treating the surplus commodities or their processing wastes which will permit their storage to facilitate industrial use must be developed. These methods may utilize freezing, drying, or controlled fermentation, or a combination of any or all of these factors. Optimum conditions for storage of vegetables or processed vegetables will require determination. In considering the industrial utilization of vegetable products, proper storage is necessary. Studies of temperature, humidity, and the use of inert gases will be included in such a program.

Pigments.

4. Carotinoid pigments (fat-soluble red and yellow pigments) are present in carrots, spinach, tomatoes, squashes, and pumpkins. The development of improved methods for their recovery from these surplus commodities will be investigated. Uses for these pigments have been found in the medicinal industry and in the coloration of commercial materials.

5. Flavins (water-soluble pigments) are greenish-yellow pigments which probably are present in vegetables. Practically no information on the nature or content of flavins in vegetable sources is available. Studies will be initiated to secure the knowledge necessary to evaluate their possible utilization in industrial fields.

6. Chlorophyll (fat-soluble green pigments) investigations will be carried out to determine the economic feasibility of preparing chlorophyll from the deep-green vegetables of which spinach appears to offer most promise. These studies will follow closely and will be coordinated with the chlorophyll program outlined in the section on Alfalfa, Part III.

7. Anthocyanins (water-soluble, bluish-red pigments) are found chiefly in beets and are most abundant in young and rapidly growing tissue. Studies on the preparation of beet pigment and on the determination of its properties will be made. Possible uses as a coloring agent will receive attention.

Pectin.

8. Vegetable pulps are relatively rich in pectins. Investigations will be initiated to develop methods for producing pectin from vegetable sources. Physicochemical and other studies similar to those described under Pectin, part III, will be made.

Oils and fats.

9. Seeds, skins, and plant leaves contain the major portion of the fats and oils in vegetables. Except that they are not nondrying oils, relatively meager information is available on their chemical and physical properties and on their components. Research will be done to supply this information. This phase of the work will follow closely that presented in Vegetable Fats and Oils, part III.

Vegetable waxes.

10. Of the vegetables, Brussels sprouts, cabbage, and turnips are the most important sources of waxes. Methods will be developed for preparing the waxes and for separating their components. The properties of the waxes and their constituents will be determined and their possible industrial utilization evaluated.

Byproducts.

11. Investigations will be undertaken to determine the nature and possible industrial utilization of the various byproducts derived from vegetables. These include such substances as proteins, sugars, amino acids, enzymes, and fibrous substances.

The protein content of vegetables, excepting the various seeds, is much lower than that of many other food materials. Comparatively little is known at present regarding nonseed vegetable proteins and basic investigations must be made before the various vegetables may be soundly evaluated as possible sources for these nitrogen compounds and their various derivatives. Certain of the vegetables, notably asparagus, are of interest as possible sources of specific amino acids; and the potentialities of these commodities for such compounds will be studied.

The various carbohydrates of vegetables need further investigation from the viewpoint of new and extended uses, and such studies will be made on those vegetables that are particularly rich in this class of compounds.

When considered on the dry basis, there is, relatively speaking, but a small quantity of fiber left from the pomace or residue after other valuable materials have been recovered. Attention will be devoted to this fibrous material, which apparently is largely hemicellulosic in type. (See Hemicellulose in Agricultural Wastes, pt. III.)

Fermentation and composting.

12. Microbiological studies on vegetables will be carried on with the aim of developing profitable methods for the production of useful materials. Various micro-organisms under a variety of conditions will be tested on vegetable products. (See Fermentation, pt. III, for a detailed description of the program.) Methods for the development of artificial manures from vegetable wastes will be investigated. This work will follow closely the program outlined in the section on Composts and Soil Enrichment in Agricultural Wastes, part III.

Pilot-plant operations.

13. Promising laboratory results will be transferred to the pilot-plant scale, and chemical engineering studies will be made in connection with subsequent transferal to industrial processors.

Economic analyses.

14. The importance of economic studies, as an integral part of the research program for the industrial utilization of vegetables, cannot be overemphasized. Such studies will include a broad economic survey of the potential and actual vegetable surpluses and their geographical distribution, particularly in relation to existing processing facilities. It also will include a careful evaluation of the economic possibilities of developing new and extended industrial uses for vegetables as such, as well as uses for their individual components.

ALFALFA

Alfalfa is the preeminent forage crop both from the standpoint of farm value and of production, the annual output approximating 25 million tons. Its present importance and its possibilities for future industrial development are due to a number of factors. These are rapid growth, abundant yields, from two to eight crops being harvested each season, and ease of hybridization, many strains having been developed that adapt it to various climatic and soil conditions. In common with other nodule-forming legumes, alfalfa has the ability to utilize atmospheric nitrogen and build it into plant substance. Thus, the soil may be improved instead of depleted in regard to nitrogen. The crop is, therefore, of great value in programs of soil enrichment, crop rotation, and offers promise for use in soil conservation work because of its deep root system. Of great significance is the possible use of alfalfa as a substitute crop, particularly if diversion to industrial uses can be accomplished.

Most of the alfalfa crop is employed as an animal or poultry feed, either in the green, dry, or ensiled form. Some is used for manurial purposes and only an insignificant amount finds an industrial outlet. Because of the demand as a feed in the winter months, the processing of alfalfa leaves to a dry, pulverized condition has been a profitable operation in spite of the fact that the material in some cases must be transported over long distances; annual production of processed alfalfa averages 255 thousand tons, having a value of about \$5,600,000.

Direct benefits accruing from a program designed to increase the industrial utilization of alfalfa would, no doubt, be considerable not only in the improvement of the processing operations but also in production of a uniform product of high quality. Resultant increased uses of processed alfalfa for feed purposes seems almost a certainty.

Insofar as the industrial utilization of alfalfa is concerned, the potentially important components are the proteins and the pigments. Very little progress has been made in developing methods for preparing and studying the proteins, chiefly because the usual process of drying this crop converts the protein into an insoluble form. If this difficulty can be overcome, alfalfa which contains 20 to 25 percent protein would become an important source of cheap commercial protein. The pigments of interest are chlorophyll and the carotinoid class of compounds. These are utilized industrially as pharmaceuticals and as pigments for coloring soaps, foods, etc. At present

the chlorophyll and carotinoid pigments consumed in the United States are in part imported and in part produced domestically, usually from dried alfalfa leaves.

Considerable improvement can be made in the domestic process, inasmuch as the residual alfalfa meal containing the protein and other constituents is discarded. Development of uses for this meal, particularly for the protein portion, would tend to lower the cost of producing the pigments, which at present is relatively high, and therefore would facilitate disposal of the pigments in new or old commercial channels.

The following program has been drawn up with the aim of increasing the industrial uses for alfalfa.

PROPOSED RESEARCH PROGRAM

Alfalfa as a raw material.

1. All factors, including environment, that affect the growth and development of alfalfa will be studied. Breeding and development of new strains will receive attention, particularly as they influence the chemical composition of alfalfa. These studies will be carried out cooperatively with existing agencies of the Department of Agriculture and the State agricultural experiment stations.

2. Harvesting, storage, and drying studies will be instituted in order to secure a high-quality alfalfa that has undergone a minimum of biochemical change. Information on the optimum time for cutting, number of cuttings, and speed and temperature of dehydration will be obtained. Grinding and processing operations to effect the separation of leaf from stem tissue, to minimize deterioration, to reduce transportation costs, etc., will be studied.

Proteins.

3. Protein studies will be given careful consideration not only from the standpoint of developing methods for isolating either native or altered protein but also with the aim of characterizing the product and determining its composition. The limiting conditions effecting denaturation will be determined, and the possibility of employing alfalfa protein for commercial uses will be investigated. For further details of this research program, see Proteins, part III.

Green and yellow pigments.

4. Methods will be refined or developed for the preparation of chlorophyll or derived products, special consideration being given to those methods which will leave the residual constituents of the plant in such a state that they can be isolated by subsequent processing. In connection with these investigations, the role and the properties of the enzyme chlorophyllase will be examined. Fundamental studies will be conducted on the chemistry and biochemistry of chlorophyll and its condition in the plant. Further industrial uses for chlorophyll or its derivatives will be sought.

5. The carotinoid pigments of alfalfa will be isolated and characterized, and their commercial utilization will be studied. Economic methods for the separation of the yellow pigments from chlorophyll will be examined.

Fibrous matter.

6. The cellulose, hemicellulose, pectin, and lignin constituents of alfalfa will be determined quantitatively, and methods for separating and utilizing these materials will be investigated. Research programs, fundamental and applied, on these products are presented in detail in the sections on Cellulose, Pectin, and Agricultural Wastes, part III.

Byproducts.

7. The oils, fats, waxes, sugars, coumarin, and other minor constituents will receive attention in regard to isolation, structure, and application to new or extended uses. These studies will be designed to establish a complete inventory of the chemical constituents of alfalfa.

Pilot-plant operations.

8. Pilot-plant studies will be performed on the production of chlorophyll, the carotinoid pigments, and proteins from alfalfa. Results of industrial promise on other constituents likewise will be subjected to large-scale operations.

DAIRY PRODUCTS

In part II it is pointed out that because milk and milk products are perishable, surpluses do not exist in the sense that there is a large carry-over from one period of excess production beyond the next one. Ordinarily all fluid milk which is not consumed directly as human food is converted into the more stable manufactured products such as butter, cheese, evaporated milk, etc. When excessively large quantities of these products accumulate, the demand for them is stimulated by the industry through price adjustments; hence milk surpluses become most apparent in unsatisfactory returns for these secondary dairy products. The occurrence of serious seasonal milk surpluses has made it necessary to seek for new and extended outlets for milk products that will bring the most satisfactory returns.

Milk as such for human consumption commands a price far in excess of that obtainable for any other purpose; nevertheless, conversion into butter, cheese, and other manufactured food products represents the best means now available for the utilization of milk which cannot be consumed directly. Consequently, much of the research effort has been devoted to the development of new and improved secondary food products.

Intimately associated with this need has been the problem of finding a more profitable and effective means for the utilization of the principal dairy byproducts, skim milk, and whey. Of these products about 54 billion pounds containing approximately 4.8 billion pounds of milk solids, chiefly casein and milk sugar (lactose), are annually available. The large part of this material, however, is only potentially available for manufacturing purposes, chiefly because most of skim milk is fed on the farms.

Steps to bring about increased industrial utilization of milk products must necessarily be very largely restricted to the principal dairy byproducts, skim milk and whey, and this presents the problem of finding such increased uses for the main constituents of these byproducts, casein and lactose, as will bring the greatest return. Considerable progress has been made in this direction, our domestic production of casein having increased from about 18 million pounds in 1921 to

about 72 million pounds in 1937. Much of the domestically produced casein is of poor quality; but more important than this has been the great lack of uniformity of the domestic product, which undoubtedly has prevented a broader application for industrial purposes. While casein is by far our most important commercial protein, its consumption has been largely restricted to a few outlets, about five-sixths of the total supply being used for paper sizing and glue. Likewise, the present uses for lactose are so few as to require only a small percentage of the total amount available. The utilization of dairy products, such as butter, cheese, etc., for other than food purposes does not appear to offer much promise.

The following is an outline of proposed research for new and extended industrial uses for dairy byproducts. The development of detailed projects within these fields will take into consideration the surplus situation of dairy byproducts, the background of information now available, and related research now active in the Department and other research organizations.

PROPOSED RESEARCH PROGRAM

Research projects directed toward more extensive utilization of dairy byproducts should be selected from the following:

Casein.

1. Fundamental studies on the chemistry of casein, including structure, polymerization, depolymerization, hydrolysis, hydration, temperature effects, etc.; preparation of components of casein and fundamental studies of their chemistry; and preparation of derivatives of casein and fundamental studies on their chemistry. (See discussion under Proteins, pt. III.)

2. Application of fundamental knowledge obtained under 1 to improvement in products now made from casein, such as adhesives, plastics, and fibers, and to the invention of new processes and products involving casein and its derivatives.

Lactose.

3. Application of fundamental knowledge of the chemistry of lactose and of its derivatives, and of bacteriology and enzymology, to improvements in existing processes for making and utilizing these substances. (For further discussion see Sugars under Starches and Sugars in pt. III.)

4. Application of knowledge obtained under 3 to the investigation of new processes and products involving lactose and its derivatives.

5. Fermentation studies on lactose and the application of results to the devising of new industrial uses. (For further discussion see Fermentation in pt. III.)

Other products.

6. Fundamental studies on the chemistry of whey protein, and application of fundamental knowledge obtained to improvement in methods of isolating whey protein and devising industrial uses for it.

7. Improvement in methods of concentrating riboflavin from whey; and application of knowledge of the characteristics of riboflavin to devising industrial uses for this substance.

PROTEINS

Proteins represent the largest source of organic nitrogen compounds in the world. The animal kingdom, seeds, and alfalfa are particularly rich in proteins. Their occurrence in such various forms, as leather, horns, hoofs, crustacean shells (lobster), tortoise shell, alligator skin, wool, hair, silk, etc., suggests the possible production of artificial, superior substitutes for these products by controlled synthetic processes. This consideration, as well as their interesting properties and the importance of their role in nature, has attracted the attention of industrial groups to their potentialities.

To some extent, proteins have already found industrial application but not to the degree that might reasonably be expected. Of the commercial proteins, namely, casein from milk, soybean protein, zein from corn, and blood albumen, the first mentioned is by far of greatest volume in present consumption, about 73 million pounds being consumed in 1937, of which 67½ million pounds were produced domestically from milk. The distribution of casein for various purposes is approximately as follows: 67 percent for paper sizes, 16 percent for glue, 5 percent for cold-water paints, 3 percent for plastics, and 8 percent for miscellaneous uses.

It is to be noted that only 3 percent of the total casein is employed in the plastics industries for the production of artificial horn and like materials. This particular development has not kept pace with the tremendous expansion of the plastics industries as a whole, mainly because of the time-consuming nature of the current methods for converting proteins to plastics and the absorptive capacity of these products for water. Additional fundamental information and the discovery of new methods for polymerizing proteins to improved fibrous forms (artificial wool is produced commercially, although not in the United States) or layer-like forms are required to increase the consumption and, hence, production of proteins.

The broad objectives of a proposed program therefore should be: (1) The determination of the cheapest animal or vegetable proteins available for industrial utilization; (2) the application of the most modern physicochemical methods, which have been strikingly successful in dealing with enzymes and viruses, to the scientifically prosaic, and in recent years relatively neglected, proteins, present in agricultural commodities; (3) the collection of precise data on the physical properties of the most common proteins; and (4) of greatest importance, the investigation of the chemical properties and constitution of proteins. This information will be of primary importance in extending present and in evaluating and developing new uses of proteins.

PROPOSED RESEARCH PROGRAM

The following work will be undertaken:

Agricultural.

1. Effect of nutrient and climatic conditions and varietal and genetic changes on the kind and amount of protein produced in the roots, stalks, leaves, and seeds of plants and in the hair, skin, and body of animals and milk. Studies of this sort offer a logical attack on the problem dealing with the development of cheaper and specific kinds of proteins. Work on this phase will be in cooperation with

related production research of State experiment stations and the Department of Agriculture.

Isolation and purification.

2. Preparation of either unaltered or modified proteins by new or refined chemical or physical methods from hydrated or from dehydrated materials by solvent extraction. Investigation of the possible change in state of proteins on isolation. Fractionation, purification, and particularly crystallization of proteins by new and modern physical or chemical methods for preparation of homogeneous proteins will receive major attention.

Identification and classification.

3. Development of physical and chemical methods for identifying and characterizing the different plant and animal proteins or their constituents; investigation of new and evaluation of old systems for classification of proteins.

Analytical.

4. Development of new or improved methods for quantitatively estimating proteins and the amino acids contained in protein; determination of the amounts of the various amino acids in proteins occurring in agricultural commodities.

Physicochemical.

5. Application of methods for determination of the molecular size and shape of proteins; investigation of properties of monomolecular and polymolecular surface films as related to the configuration and function of proteins and enzymes; securing exact data on the various physical properties of pure plant and animal proteins, polypeptides, and amino acids.

Decomposition into simpler units—amino acids and polypeptides.

6. Complete and stepwise acidic, basic, and enzymic hydrolysis of proteins for preparation of amino acids, and of polypeptides having various mean molecular weights; separation of amino acids or modified amino acids, and polypeptides by physical and chemical methods—molecular distillation as a means of separating modified amino acids is particularly attractive; synthesis of and chemical investigation on amino acids and polypeptides; fission of proteins by new methods.

Polymerization.

7. Development of methods for polymerizing proteins, polypeptides, or amino acids to fibrous or nonfibrous materials.

Constitution.

8. Modification of the surface of normal protein molecules, including enzymes and monomolecular films, by application of mild reactions; subsequent appropriate modification to determine the number and kind of active groups present on the periphery of the molecule; determination of the number and the arrangement of the amino acids in the molecule by degradative and synthetic means; employment of physicochemical methods and modern concepts in the elucidation of the spatial configuration and structure of proteins and the nature of the primary and secondary valence bonds.

Denaturation.

9. Effect of physical and chemical agents on the primary and secondary valence forces in proteins and relation of dehydration to denaturation of proteins; determination of active groups on surface and configuration of denatured molecules; development of methods for reverting denatured proteins. The relation between the natural and denatured proteins is of fundamental importance from the nutritional point of view as well as in the development of new industrial products, as only denatured proteins are rapidly attacked by the proteolytic enzymes.

Prosthetic groups.

10. The fundamental investigation of proteins containing prosthetic groups; to determine the nature of the prosthetic group and type of binding with proteins.

TOBACCO

The current world situation with respect to tobacco production has been previously considered in part II. That discussion considers the changes which have taken place during recent years with regard to the foreign and domestic demands for certain types of tobacco, and the adverse effects of these changes on tobacco growers in the United States.

Need for new uses and outlets for the fire-cured and dark air-cured types of tobacco has been especially acute in recent years owing to the current world trend toward the use of lighter, milder tobaccos and trends toward self-sufficiency in the production of similar types of tobacco in foreign countries, which have resulted in serious losses in both our foreign and domestic markets for these heavier types.

Producers of heavy tobaccos are not alone in their need for valuable new uses for tobacco. As a result of seasonal conditions, large portions of the tobacco crop are produced that are less desirable or unfit for normal leaf tobacco purposes. Each year there is a low-grade portion of every crop that should be used if practicable for byproducts instead of being offered in competition in the regular leaf tobacco channels.

Rapid expansion in many foreign countries in the production of important flue-cured tobacco may also result in reduced exports of this type. It is possible that a need will arise similar to that now existing in the dark types for new and important outlets other than for smoking and chewing. The constant improvement being effected by tobacco agronomists, chemists, and other scientific workers upon the admittedly superior United States tobaccos, is recognized as an important factor in retaining our share of the foreign markets. Trade barriers erected by foreign countries and the stimulation that is being given to an ever-increasing foreign production of similar types may eventually offer definite limitations to our tobacco exports of all types.

It is difficult to increase the per capita consumption of tobacco, yet there may be ways to forestall the present shift in consumption of types, thereby preventing the further decline or even extinction of types like the cigar types, with the resulting damage to the producers concerned.

Tobacco, once properly processed, becomes a relatively non-perishable product if kept free of insects. It can be kept in storage for 3 or 4 years with no serious deterioration in its chemical and physical make-up. This is a fortunate circumstance, both from the standpoint of smoking and byproducts usage, since if tobacco were a commodity requiring quick conversion to ultimate products, the economics of the industry would be far different from what it is today. By virtue of its nonperishable nature a year-around factory processing industry can be operated on a supply and demand basis.

Another fortunate circumstance connected with tobacco is that the characteristic constituent, nicotine, is highly toxic to insect life and is used in several forms which render it useful both as a contact insecticide and stomach poison. It is in the insecticide field where the greatest hope apparently lies for increased consumption of tobacco products. Researches during the past 10 years have developed wider applications. Formerly nicotine was used only as a contact insecticide in the form of a spray or dust to control a limited group of soft-bodied sucking insects. Developments of the past 5 years have greatly increased the efficiency of nicotine and enlarged its use in this field. During the past 10 years other experimental work has developed new nicotine compounds which are adapted for the control of chewing insects and which are more nearly free of the human health hazards of the metallic poisons.

This new use of nicotine in the so-called "fixed nicotine" compounds opens a broad field. Such use in the apple orchards alone should offer an outlet for a considerable quantity of low grade tobacco. It is believed that other new uses can be found for common tobaccos which will give greater strength to the produce markets.

In setting up the program, it is contemplated that where existing facilities are available cooperative arrangements with the existing agencies will be established. This will include cooperative arrangements with the various departmental bureaus and divisions, State experiment stations, and other State agencies, and, where feasible, with research departments of industrial establishments.

PROPOSED RESEARCH PROGRAM

Looking to the development of new and extended uses of tobacco, the following research program will be undertaken:

Agronomic.

1. Agronomic and chemical investigations will be pursued in cooperation with the production research of the Department and of State experiment stations, to develop high-nicotine tobaccos which would be suitable for industrial production of nicotine and other products. These will include plant breeding studies to develop high-nicotine strains and studies of the influence thereon of various cultural and environmental factors.

2. Studies will be undertaken in cooperation with agencies engaged in production research, to determine the effect of various cultural, varietal, environmental, and processing factors for all types of tobacco on their qualities for human consumption and to establish the relationship of these qualities to chemical composition.

Processing studies.

3. Attempts will be made, in cooperation with groups now engaged in similar work, to improve the quality of domestic cigar tobaccos by removing irritants, by conserving the natural aromatic principles, and by improving the burning properties. A larger consumption of tobacco might result from the production of a cigarette larger than the present standard small cigarette. The various economic and the technical factors involved in such a change will receive consideration.

Production of nicotine.

4. Because of the wider use of nicotine which may develop within the next few years, attention will be given to exploring the present potential sources of nicotine which now are unexploited. Studies will be directed toward the recovery of the nicotine from the vapors of tobacco factory drying machines and on the use of oxidizing agents in improving the efficiency of present extraction methods in recovery of nicotine.

Extension of uses of nicotine.

Nicotine is by far the most important byproduct of tobacco. It is an efficient insecticide which can be applied in vapor, liquid, or solid states and it is believed its use can be greatly extended.

5. Work is planned to develop compatible fungicides for use with the fixed nicotines; improved engineering methods for applying vaporized or gaseous nicotine to truck and tree crops; more efficient spreaders and activators of nicotine and its compounds with the primary purpose of reducing their cost of application.

6. Research will be made to evaluate the nicotine-combining power of silicate and aluminum minerals and to determine the possibility of protecting the nicotine of nicotine bentonite by inclusion of other organic bases to obtain greater stability than that possessed by the present straight nicotine bentonite; to evaluate the efficiency of carbohydrates, such as molasses and sugar residues, as carriers of nicotine for insecticide use; and to determine the efficiency of hydrocarbon oils of the kerosene type as nicotine carriers.

7. Studies will be conducted to adapt nicotine bentonite and similar fixed nicotine compounds to wider uses and to establish them in the field of codling moth control; to increase the number of water-soluble and oil-soluble nicotine compounds available to the entomologist; and to examine the effect of soil environment upon nicotine compounds when applied in the soil as an insecticide.

8. Fundamental information on nicotine will be obtained in order to develop new derivatives of possible industrial value, such as nicotinic acid of use in the medicinal field.

Uses for tobacco constituents other than nicotine.

9. About 30 different constituents of tobacco are known. Many of these are common and abundant in the vegetable kingdom but certain of them are specific and peculiar to tobacco. It is planned to study practical methods of isolation and the economic possibilities for commercial exploitation of the following materials: Alkaloids other than nicotine which are known to occur in tobacco; organic acids, essential oils, chlorophyll, xanthophyll, and pectin; tobacco extract free of nicotine for possible use as an insecticide spreader and as a blood coagulant for possible use in surgery; the use of cellulose in the manufacture of cigarette wrappers.

Tobacco powder.

10. To perfect and extend the use of tobacco powder as a carrier of solid or liquid insecticides or fungicides.

Farm utilization of low-grade surpluses.

11. Constructive work will be done on the farm utilization of low-grade tobaccos. Desirable farm uses for such tobaccos will be explored to facilitate removal from the regular leaf channels.

CONCLUSION

ORGANIZATION OF RESEARCH WORK

Research programs concerning new and extended industrial uses for the 16 agricultural commodities selected for initial attack at the Regional Research Laboratories have been presented in part III. In addition, some sections of this part of the report have dealt with constituents, like starch or cellulose; or with methods of treatment, like fermentation; or with products to be developed, like motor fuels. Including these, programs for 22 major subjects have been outlined.

These programs of research except perhaps the agronomic phases of the work will be grouped at the four regional laboratories. Those dealing with commodities will be placed in the laboratory most conveniently situated with regard to the area in which each commodity is produced.

All types of research programs at a particular laboratory will be interrelated. For example, the northern laboratory will deal with wheat and corn; with starch, a major constituent of wheat and corn; and with fermentation, a major method of processing wheat and corn. The motor-fuel studies will be there, too, because these deal with a major product which may be developed from starchy cereal grains. At the northern laboratory, also, studies will be carried out on the major agricultural residues, such as straw, stalks, cobs, and other inevitable byproducts of agriculture—materials that are now residues rather than sources of useful products.

In like manner, work on cellulose will be conducted at the southern laboratory and will be closely associated with the cotton investigations. Studies on vegetable oils will also be located at the southern laboratory because of their association with cottonseed and with peanuts, two of the major commodities that are principal sources of vegetable oils.

The senior members of the scientific staffs who will organize and carry out these research programs are now being selected. As soon as they are appointed under civil service these staff members will undertake the detailed study of all available information and the formulation of exact and specific projects for laboratory and engineering attack. It would be neither feasible nor useful at this time to go further into detail. It is worth while, however, to recognize and set forth here a few broad governing principles.

PLANNING A RESEARCH PROGRAM

It has already been emphasized in this report that the work of the four regional laboratories is not as comprehensive as was the survey of present and recommended research reported in part II. It is emphasized again here that the economic yardstick will be applied to every proposal for a research undertaking, so that the most useful work and the most promising investigations may be undertaken first.

However, it should also be recalled that some investigations will of necessity be merely of exploratory or of fundamental relationship to the laboratory program. Only the Government is in a position to do some of this work which is imperative in the effective development of new uses for agricultural products. In this connection, however, it is most important to recognize that no present research plan can be final. To be useful, such a program must be dynamic, changing with every new need or advance. It must guide the investigator on a sound course but not drag him back nor unduly restrict him to old or less promising fields when new and more fertile vistas are opened.

RESULTS EXPECTED

It has been said that industry succeeds in new development most often when it invests "patient money" in its research laboratories. This means simply that even when industry selects projects of most immediate value, it cannot expect results in a short time. This is even more true of Government research, because the Government should reach further out into the unknown than can most of the industrial laboratories of the country in order to increase the number of projects of more immediate value for development. Furthermore, it is often necessary for the Government to undertake types of investigation for which industry either has no immediate application or which it cannot afford. Generally, therefore, Government research must wait longer for useful industrial applications than does that of industry.

The work of the regional laboratories will be organized to take fullest possible advantage of advisory committees of expert scientific men from all Federal, State, and educational institutions. The Department will hope for and will welcome the fullest possible cooperation from industry. This cooperation will, it is expected, make for speed. It will also make the results of the new laboratories of greatest value to the "practical" research worker. It may even result in preliminary findings of the Government laboratories being taken over by those prepared to use them in accordance with the public welfare, in order that they may be promptly put into practice. The Department will encourage this. The success of the new laboratories will be tested principally by the usefulness of their work to industry and agriculture.

THE ULTIMATE OBJECTIVE

In setting up an initial program for these laboratories, the principle of "first things first" has naturally been followed. An acute surplus situation exists in certain crops, and the intent of Congress is to bring this new attack to bear on this problem as speedily as possible. The program as now set up is intended to do exactly that. Nevertheless, one familiar with economic history must be aware that with the passing of years such situations change greatly. It is conceivable that some years from now our international trade position or our agricultural output may be wholly altered, or the requirements of American industry and consumers may change. In other words, this agricultural surplus problem is not static, and plans should not be made on the supposition that it will remain fixed and unchanged.

One inevitable result of the proposed program is that basic chemical research will lead into fields where economic factors will be deci-

sive—where such questions as competition between products, the effect of changes in farm practice in a given region, the relation of tariffs to new forms and uses of a product, the effect of an altered international trade situation, the bearing of this or that line of research on national defense and like questions, must be met and answered. This requires the development of economic research complementary to the chemical studies.

For the long-range view, these laboratories will require a flexible program; and the initial program of this report is not intended to preclude changes in scope or emphasis in the future. The United States is a young and dynamic nation. It is unlikely that the present-day pattern of our economic life will be exactly the same a few decades hence. It is unlikely, moreover, that the research and educational patterns which fit our present-day needs will exactly satisfy them in the future. Experience leads us to believe quite the opposite will be true.

One certain and permanent value of these laboratories will rest on the fact of their actual physical existence. Such institutions, with their extensive equipment, libraries, and trained technical staffs, cannot be brought into being overnight. Once actually established they can be reckoned as productive national assets, if only for the reason that they will bring into stimulating conjunction a group of inquiring, creative minds and the assemblage of unusual facilities which not only are the necessary tools of discovery in peacetimes, but are doubly valuable in times of national emergency.

But it is believed that the most important potential values of the enterprise are, in the nature of things, not predictable. In a broad sense, all research work is founded upon the faith that, in the long run, knowledge is a better guide to human action than ignorance; and it should not be thought that the areas of our ignorance are now small and unimportant. On the contrary, every extension of the area of the known widens its periphery of contact with the unknown. During the course of this survey, outstanding investigators in every line of work have repeatedly expressed this feeling of profound ignorance and the conviction that within the area of the unknown there are undreamed-of potentialities. The new laboratories are being founded with what is thought to be a soundly conceived program of work addressed primarily to the present-day surplus problem. Beyond that, as all directors of long-time enterprises know, the important thing is to shape all activities so that they may be quickly responsive to those needs and opportunities which the future will surely bring forth.

It seems proper to add a word as to the human equation. The outcome of scientific work is, after all, gauged closely to the caliber of the man who does it. The men charged with the responsibility of establishing these institutions are well trained in their fields, and they are undertaking the work with enthusiasm. While discouraging any expectations of quick and spectacular results, they are confident, nevertheless, that these contemplated lines of research will yield, finally, great benefits to agriculture and to the whole community. Judging from all past experience, our feeling is that these laboratories, well-equipped and with a competent and enthusiastic staff, can be expected to return to the country fully satisfactory dividends of service upon its investment.

PART IV. APPENDIX

Acknowledgment is made to the following individuals and organizations, without whose whole-hearted cooperation and support the completion of the survey and the compilation of this report would have been impossible.

While many individuals representing organizations in administrative or technical capacities have contributed liberally, for the sake of brevity only the organizations which they represent are listed.

LIST OF ORGANIZATIONS CONSULTED

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| <p>Abbott Laboratories, North Chicago, Ill.
 Acme Breweries, San Francisco, Calif.
 Acme White Lead & Color Works, Detroit, Mich.
 Agfa Ansco Corporation, Binghamton, N. Y.
 Agicide Laboratories, Los Angeles, Calif.
 Agricultural Council of California, Sacramento, Calif.
 Agricultural Engineering Foundation, San Francisco, Calif.
 Akron University, Akron, Ohio.
 Alabama Extension Service, Auburn, Ala.
 Alabama Polytechnic Institute and Agricultural Experiment Station, Auburn, Ala.
 Alabama, University of, Tuscaloosa, Ala.
 Albers Bros., Milling Co., Peoria, Ill.; Seattle, Wash.
 Alcoma Corporation, Temple Town, Fla.
 Alexander, Jerome, New York, N. Y.
 Allied Chemical & Dye Corporation, New York, N. Y.
 Allied Kid Co., Wilmington, Del.
 Allied Laboratories, Indianapolis, Ind.
 Allied Mills, Peoria, Ill.
 Aluminum Co. of America, New Kensington, Pa.
 Amalgamated Leather Cos., Inc., Wilmington, Del.
 Amalgamated Sugar Co., Nyssa, Oreg.
 American Agricultural Chemical Co., Newark, N. J.
 American Aniline Products Co., New York, N. Y.
 American Anode, Inc., Akron, Ohio.
 American Association of Operative Millers, Kansas City, Mo.
 American Bakeries Co., Atlanta, Ga.</p> | <p>American Beet Seed Co., Rocky Ford, Colo.
 American Bemberg Corporation, Elizabethton, Tenn.
 American Butter Co., Kansas City, Mo.
 American Butter Institute, Chicago, Ill.
 American Can Co., Chicago, Ill.; Houston, Tex.; New Orleans, La.; Portland, Oreg.
 American Chemical Society, Washington, D. C.
 American Chlorophyll Co., North Fairfax, Va.
 American Corn Millers Federation, Chicago, Ill.
 American Cotton Manufacturers Association, Charlotte, N. C.
 American Cream of Tartar Co., San Francisco, Calif.
 American Crystal Sugar Co., Denver, Colo.
 American Cyanamid Co., New York, N. Y.; Stamford, Conn.
 American Distillery Co., Pekin, Ill.; San Francisco, Calif.
 American Dry Milk Institute, Chicago, Ill.
 American Enka Corporation, Enka, N. C.
 American Extract Co., Port Allegany, Pa.
 American Farm Bureau Federation, Washington, D. C.
 American Feed Manufacturers Association, Chicago, Ill.
 American Fruit Growers, Inc., Wenatchee, Wash.
 American Hair & Felt Co., Chicago, Ill.
 American Institute of Baking, Chicago, Ill.
 American Maize Products Co., Roby, Ind.
 American Miller, Chicago, Ill.
 American Molasses Co., Inc., New York, N. Y.</p> |
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- American Oak Leather Co., Cincinnati, Ohio.
 American Oil Chemists Society, New Orleans, La.
 American Petroleum Industries Committee, Chicago, Ill.
 American Plastics Corporation, Bainbridge, N. Y.
 American Products Co., Cincinnati, Ohio.
 American Products Manufacturing Co., New Orleans, La.
 American Rubber Producers, Salinas, Calif.
 American Silk Spinning Co., Providence, R. I.
 American Smelting & Refining Co., Salt Lake City, Utah.
 American Snuff Co., Memphis, Tenn.
 American Sugar Cane League, New Orleans, La.
 American Sugar Refinery, Chalmette, La.
 American Thread Co., Willimantic, Conn.
 American Tobacco Co., Richmond, Va.
 American Viscose Co., Marcus Hook, Pa.
 American Writing Paper Co., Holyoke, Mass.
 American Yarn & Processing Co., Mount Holly, N. C.
 Anderson, Clayton & Co., Houston, Tex.; Los Angeles, Calif.
 Andrews, A. B., Lewiston, Maine.
 Anheuser-Busch, Inc., St. Louis, Mo.
 Antioch College, Yellow Springs, Ohio.
 Applied Research Laboratories, Dayton, N. J.
 Arabol Manufacturing Co., Brooklyn, N. Y.
 Archer-Daniels-Midland Co., Minneapolis, Minn.
 Arco Co., Cleveland, Ohio.
 Arco Co. of California, Ltd., Los Angeles, Calif.
 Arizona, University of, and Agricultural Experiment Station, Tucson, Ariz.
 Arkansas Agricultural Industrial Commission, Little Rock, Ark.
 Arkansas Farm Bureau Federation, Little Rock, Ark.
 Arkansas Forestry Commission, Little Rock, Ark.
 Arkansas, University of, and Agricultural Experiment Station, Fayetteville, Ark.
 Arlington Mills, Lawrence, Mass.
 Armour & Co., Chicago, Ill.
 Armour Institute of Technology, Chicago, Ill.
 Armour Institute of Technology, Research Foundation, Chicago, Ill.
 Armour Leather Co., Chicago, Ill.; Newberry, Pa.; Sheboygan, Wis.
 Armstrong Cork Co., Lancaster, Pa.; Pensacola, Fla.
 Armstrong Paint & Varnish Works, Chicago, Ill.
 Arnold Hoffman Co., Providence, R. I.
 Arnold Print Works, North Adams, Mass.
 Aroostook County Council and County Farm Bureau, Presque Isle, Maine.
 Arrow Distilleries, Inc., Peoria, Ill.
 Arsem, Wm. C., Schenectady, N. Y.
 Art Loom Corporation, Philadelphia, Pa.
 Associated Oil Co., Associated, Calif.
 Associated Seed Growers, Inc., New Haven, Conn.
 Association of Land Grant Colleges, Reno, Nev.
 Astatic Microphone Laboratory, Inc., Youngstown, Ohio.
 Athol Manufacturing Co., Athol, Mass.
 Atlas Powder Co., Wilmington, Del.
 Autoxygen, Inc., New York, N. Y.
 Avondale Mills, Birmingham, Ala.
 Axton-Fischer Tobacco Co., Louisville, Ky.
- B
- Bacon, Charles V., New York, N. Y.
 Bain Peanut Co. of Texas, Fort Worth, Tex.
 Bakelite Corporation, Bloomfield, N. J.
 Baker Castor Oil Co., Bayonne, N. J., New York, N. Y.
 Bakers Helper, Chicago, Ill.
 Bakers Weekly, Chicago, Ill.
 Bancroft & Sons, Wilmington, Del.
 B. and B. Chemical Co., Cambridge, Mass.
 Barnes, S. O., & Co., Gardens, Calif.
 Barrow-Agee Laboratories, Memphis, Tenn.
 Basic Vegetable Products Co., Vacaville, Calif.
 Battelle Memorial Institute, Columbus, Ohio.
 Battle Creek Food Co., Battle Creek, Mich.
 Baylor University, Waco, Tex.
 Bay State Chemical Co., Peabody, Mass.
 Bear Creek Orchards, Medford, Oreg.
 Beatrice Creamery Co., Chicago, Ill.
 Beavers-Remmers-Graham Co., Dayton, Ohio.
 Beckman, J. W., Berkeley, Calif.
 Beech-Nut Packing Co., Canajoharie, N. Y.
 Bell Telephone Laboratory, New York, N. Y.
 Bemger, Ernest B., Wilmington, Del.
 Bennett, Inc., Cambridge, Mass.
 Ben Venne Laboratories, Inc., Cleveland, Ohio.
 Berg, Chas. W., Laboratories, Philadelphia, Pa.
 Berghausen Chemical Co., Cincinnati, Ohio.
 Bernat, Emile & Sons, Jamaica Plains, Mass.

- Berry Bros., Detroit, Mich.
 Best Foods, Inc., Bayonne, N. J.; San Francisco, Calif.
 Bibb Manufacturing Co., Columbus, Ga.
 Bigelow-Sanford Carpet Co., Amsterdam, N. Y.; Thompsonville, Conn.
 Bio-Products Co., Inc., Astoria, Oreg.
 Bird & Sons, East Walpole, Mass.
 Birdseye Laboratories, Boston, Mass.
 Bireley's California Fruit Products, Los Angeles, Calif.
 Bishopric Products Co., Cincinnati, Ohio.
 Blair Laboratory, Newark, N. J.
 Block Laboratories, Winnetka, Ill.
 Bloede, Victor G., Co., Inc., Baltimore, Md.
 Blue Lyon Farming Co., Stockton, Calif.
 Blue Valley Creamery Co., Chicago, Ill.
 Bonneville Dam Project, Portland, Oreg.
 Borden Co., Chicago, Ill.; New York, N. Y.; Syracuse, N. Y.
 Borden Dairy Delivery Co., San Francisco, Calif.
 Borden Dry Milk Co., Bainbridge, N. Y.
 Borinquen Research Laboratory, Eustis, Fla.
 Boston University, Boston, Mass.
 Boston Woven Hose & Rubber Co., Boston, Mass.
 Bowen, E. P., Jr., Tifton, Ga.
 Boyce-Thompson Institute for Plant Research, Superior, Ariz.; Yonkers, N. Y.
 Braden-Sutphin Ink Co., Cleveland, Ohio.
 Bradford-Durfee Textile School, Fall River, Mass.
 Brandon Mills, Greenville, S. C.
 Braun-Knecht-Herman Co., San Francisco, Calif.
 Breeding and Laboratory Institute, Brooklyn, N. Y.
 Breon, Geo. A. & Co., Inc., Kansas City, Mo.
 Bridges, Malcolm, Richmond, Va.
 Brigham Young University, Provo, Utah.
 Broeman, F. C., & Co., Cincinnati, Ohio.
 Brogden Co., Pomona, Calif.
 Brooklyn Polytechnic Institute, Brooklyn, N. Y.
 Brown, Andrew Co., Los Angeles, Calif.
 Brown Co., Berlin, N. H.; Portland, Maine.
 Brown, H. H., New York, N. Y.
 Brown, Sewell S., & Co., Los Gatos, Calif.
 Bruce, E. L., Co., Memphis, Tenn.
 Bruning Tobacco Extract Co., Lynchburg, Va.
 Brunswick-Balke-Collender Co., Muskegon, Mich.
 Buchanan, C. G., Chemical Co., Norwood, Ohio.
- Buckeye Cotton Oil Co., Memphis, Tenn.
 Burns, W. H., Co., Philadelphia, Pa.
 Butler University, Indianapolis, Ind.
- C
- Cabel Chemical Co., Huntington, W. Va.
 Calavo Growers of California, Los Angeles, Calif.
 Calgon, Inc., Pittsburgh, Pa.
 California Agricultural Council, Sacramento, Calif.
 California Agricultural Prorate Commission, Sacramento, Calif.
 California Almond Growers Exchange, Sacramento, Calif.
 California & Hawaiian Sugar Refining Corporation, San Francisco, Calif.
 California Bean Straw Association, Oxnard, Calif.
 California Canning Peach Growers, San Francisco, Calif.
 California Cattleman's Association, San Francisco, Calif.
 California Central Fibre Corporation, El Centro, Calif.
 California Consumers Corporation, Los Angeles, Calif.
 California Crop Reporting Service, Sacramento, Calif.
 California Date Growers Association, Indio, Calif.
 California Dried Fruit Research Institute, San Francisco, Calif.
 California Farm Bureau Federation, Berkeley, Calif.
 California Fig Growers and Packers, Fresno, Calif.
 California Fig Institute, Fresno, Calif.
 California Filter Co., San Francisco, Calif.
 California Flax Seed Products Co., Vernon, Calif.
 California Fruit Exchange, Sacramento, Calif.
 California Fruit Growers Exchange, Los Angeles, Calif.; Ontario, Calif.
 California Hay, Grain & Feed Dealers Association, Sacramento, Calif.
 California Institute of Technology, Pasadena, Calif.
 California Juices, Anaheim, Calif.
 California Lima Bean Growers Association, Oxnard, Calif.
 California Olive Association, San Francisco, Calif.
 California Packing Corporation, San Francisco, Calif.
 California Products Co., Fresno, Calif.
 California Prune & Apricot Growers Association, San Jose, Calif.
 California Spray Chemical Corporation, Richmond, Calif.
 California, University of, and Agricultural Experiment Station, Berkeley, Calif.

- California Vegetable Concentrates, Inc., Los Angeles, Calif.
- California Walnut Growers Association, Los Angeles, Calif.
- California Wool Growers Association, San Francisco, Calif.
- Calloway Mills, La Grange, Ga.
- Caltex Co., Milpitas, Calif.
- Campbell Soup Co., Camden, N. J.
- Canners' League of California, San Francisco, Calif.
- Canning Machinery & Supply Association, Battle Creek, Mich.
- Cannon Mills, Inc., Kannapolis, N. C.
- Cargille Grain Co., Minneapolis, Minn.
- Carnation Co., Milwaukee, Wis.
- Carnegie Institute of Technology, Pittsburgh, Pa.
- Carolina Aniline & Extract Co., Charlotte, N. C.
- Casein Manufacturing Co. of America, Bainbridge, N. J.
- Case School of Applied Science, Cleveland, Ohio.
- Catalin Corporation, Fords, N. J.
- Caterpillar Tractor Co., East Peoria, Ill.
- Celanese Corporation of America, New York, N. Y.
- Celluloid Corporation, Newark, N. J.
- Cellulose Research Corporation, East Alton, Ill.
- Celotex Corporation, Marrero, La.
- Centennial Flouring Mills, Spokane, Wash.; Tacoma, Wash.
- Central Arizona Light & Power Co., Phoenix, Ariz.
- Central California Beet Sugar Growers' Association, Stockton, Calif.
- Century Distilling Co., Peoria, Ill.
- Certified Laboratories, Inc., New York, N. Y.
- Challenge Cream & Butter Association, Los Angeles, Calif.
- Champion Fibre Co., Canton, N. C.
- Champion Paper & Fiber Co., Hamilton, Ohio.
- Charlotte Chemical Laboratories, Inc., Charlotte, N. C.
- Charlton Laboratories, Inc., Portland, Ore.
- Chemical Foundation, New York, N. Y.
- Chemical Foundation of Kansas, Atchison, Kans.
- Cheney Bros., Manchester, Conn.
- Chez Francois, Miami, Fla.
- Church of Jesus Christ of Latter Day Saints, Salt Lake City, Utah.
- Citrus Improvement Co., Sanford, Fla.
- Citrus Juice & Flavor Co., Santa Ana, Calif.
- Clapp, Albert L., Laboratories, Danvers, Mass.
- Clark Publishing Co., Charlotte, N. C.
- Clatsop County Bent Grass Association, Astoria, Ore.
- Clemson Agricultural College, Clemson, S. C.
- Cleveland Laboratories & Manufacturing Co., Inc., Newark, N. J.
- Cleveland Tractor Co., Cleveland, Ohio.
- Clinton, Co., Clinton, Iowa.
- Cluett Peabody & Co., Inc., Troy, N. Y.
- Colgate-Palmolive-Peet Co., Jersey City, N. J.
- Collins & Aikman Corporation, Philadelphia, Pa.
- Colonial Sugars, Gramercy, La.
- Colorado College, Colorado Springs, Colo.
- Colorado School of Mines, Golden, Colo.
- Colorado State College of Agriculture and Mechanic Arts and Agricultural Experiment Station, Fort Collins, Colo.
- Colorado, University of, Boulder, Colo.
- Columbia Fruit Growers Association, The Dalles, Ore.
- Columbia Mills, Inc., New York, N. Y.
- Columbia University, New York, N. Y.
- Columbus Laboratories, Chicago, Ill.
- Commander-Larrabee Corporation, Buffalo, N. Y.; Kansas City, Mo.; Minneapolis, Minn.
- Commercial Creamery Co., Spokane, Wash.
- Commercial Solvents Corporation, Agnew, Calif.; Harvey, La.; Peoria, Ill.; Terre Haute, Ind.
- Congoleum-Nairn, Inc., Kearny, N. J.
- Connecticut Agricultural Experiment Station, New Haven, Conn.
- Connecticut State College, Storrs, Conn.
- Consolidated Dairy Products, Inc., Seattle, Wash.
- Container Corporation of America, Chicago, Ill.
- Continental Can Co., Chicago, Ill.; New Orleans, La.; Seattle, Wash.
- Cook Research Laboratories, Ltd., Memeo Park, Calif.
- Cooperative Dairy Association, Portland, Ore.
- Cooperative Laboratories, Monticello, Fla.
- Coors Porcelain Co., Golden, Colo.
- Corn Belt Distilling Co., Peoria, Ill.
- Cornell University, Ithaca, N. Y.; New York, N. Y.
- Corn Industries Research Foundation, New York, N. Y.
- Corn Products Refining Co., Argo, Ill.
- Cotton Research Foundation, Memphis, Tenn.
- Cotton Textile Institute, Inc., New York, N. Y.
- Creamery Package Manufacturing Co., Chicago, Ill.
- Crosse & Blackwell Co., Baltimore, Md.
- Crossett Chemical Co., Crossett, Ark.
- Crossett Paper Mills, Crossett, Ark.
- Crown Cork & Seal Co., Inc., Baltimore, Md.
- Crown-Zellerbach Paper Co., Camas, Wash.
- Cudahy Packing Co., Los Angeles, Calif.; Omaha, Nebr.
- Cultex Co., Milpitas, Calif.

Curtis & Tompkins, Ltd., San Francisco, Calif.
 Cutler-Hammer, Inc., Milwaukee, Wis.
 Cutter Laboratories, Berkeley, Calif.

D

Dairymen's League Cooperative Association, Syracuse, N. Y.
 Dallas News, Dallas, Tex.
 Davies-Young Soap Co., Dayton, Ohio.
 Davis & Bennett, Inc., Worcester, Mass.
 Dawe's Vitamins, Inc., Chicago, Ill.
 Deavitt Laboratories, Inc., Chicago, Ill.
 Defensive Diet League of America, Toledo, Ohio.
 Dehls & Stein, Newark, N. J.
 Delaware, University of, and Agricultural Experiment Station, Newark, Del.
 De Leon Peanut Co., De Leon, Tex.
 Delta & Pine Land Co., Scott, Miss.
 Demko Bros., Altoona, Fla.
 Dennison Manufacturing Co., Framingham, Mass.
 Detroit Graphite Co., Detroit, Mich.
 Detroit Lubricator Co., Detroit, Mich.
 Detroit Testing Laboratory, Detroit, Mich.
 Devoe and Reynolds Co., Inc., Louisville, Ky.; Newark, N. J.; New York N. Y.
 Dexter Paper Manufacturing Co., Windsor Locke, Conn.
 Difco Laboratories, Detroit, Mich.
 Dill & Collins Co., Philadelphia, Pa.
 Dittlinger Roller Mills, New Braunfels, Tex.
 Dixie Mercerizing Co., Chattanooga, Tenn.
 Dow Chemical Co., Midland, Mich.
 Dow, I. O. Chemical Co., Long Beach, Calif.
 Drackett Chemical Co., Cincinnati, Ohio.
 Dried Foods Products Co., Maywood, Calif.
 Drumbheller Analytical Laboratory, Spokane, Wash.
 Dry Milk Co., Bainbridge, N. Y.
 Duke University, Durham, N. C.
 Duncan & Aragon-Baldwin Mills, Greenville, S. C.
 Dunlap, F. L., Chicago, Ill.
 du Pont de Nemours, E. I., & Co., Arlington, N. J.; Cleveland, Ohio; Deepwater Point, N. J.; El Monte, Calif.; Flint, Mich.; Tonawanda, N. Y.; Wilmington, Del.
 Durkee Famous Foods, Berkeley, Calif.; Elmhurst, N. J.; Portland, Oreg.

E

Eagle-Ottawa Leather Co., Grand Haven, Mich.; Whitehall, Mich.
 Eastern Manufacturing Co., Bangor, Maine.

Eastman Kodak Co., Rochester, N. Y.
 Eaton, J. S., Coconut Grove, Fla.
 Eavenson, Alban, Philadelphia, Pa.
 Eavenson & Levering, Camden, N. J.
 Ecker, Howard, Chemical Co., Cincinnati, Ohio.
 Ecusta Paper Corporation, Brevard, N. C.
 Edison, Thomas A., Inc., Orange, N. J.
 Edwal Laboratories, Inc., Chicago, Ill.
 Eff Laboratories, Inc., Cleveland, Ohio.
 Eisendrath, B. D., Memorial Laboratory, Racine, Wis.
 Ekroth Laboratories, Brooklyn, N. Y.
 El Dorado Oil Works, San Francisco, Calif.
 Electrical Testing Laboratories, New York, N. Y.
 Ellis-Foster Co., Montclair, N. J.
 Emery Industries, Inc., Cincinnati, Ohio.
 Empire State Varnish Co., Inc., Brooklyn, N. Y.
 Endicott-Johnson Co., Endicott, N. Y.
 Epstein Reynolds & Harris, Chicago, Ill.
 Erwin Cotton Mills, Inc., Durham, N. C.
 Esselen, Gustavus J., Inc., Boston, Mass.
 Ethyl Gasoline Corporation, Detroit, Mich.
 Eugene Fruit Growers Association, Moorehaven, Fla.
 Evaporated Milk Association, Chicago, Ill.
 Everglades Feed Mill, Moorehaven, Fla.

F

Farmer's Hide Bureau, New York, N. Y.
 Fertig, George A., Birmingham, Ala.
 Fibreboard Products, Inc., Stockton, Calif.
 Filtrol Co. of California, Los Angeles, Calif.
 Firestone Cotton Mills, Gastonia, N. C.
 Firestone Tire & Rubber Co., Akron, Ohio.
 Fisher Flouring Mills Co., Seattle, Wash.
 Fisk Rubber Co., Chicopee Falls, Mass.
 Fitchburg Paper Co., Fitchburg, Mass.
 Flax & Fibre Institute of America, Chicago, Ill.
 Flax Institute of the United States, Minneapolis, Minn.
 Fleischmann Laboratories, New York, N. Y.
 Fleischmann Malting Co., Chicago, Ill.
 Florida Citrus Canners Cooperative, Lake Wales, Fla.
 Florida Citrus Reserach Laboratory, Dunedin, Fla.
 Florida East Coast Growers, Miami, Fla.
 Florida, Everglades Agricultural Experiment Station, Belle Glade, Fla.

- Florida Fruit Cosmetics Co., Miami, Fla.
 Florida Fruit Industries, Inc., Orlando, Fla.
 Florida, North Agricultural Experiment Station, Quincy, Fla.
 Florida State Board of Control, Miami, Fla.
 Florida, University of, and Agricultural Experiment Station, Gainesville, Fla.
 Food Freezers, Inc., San Francisco, Calif.
 Food Machinery Corporation, Dunedin, Fla.; San Jose, Calif.
 Food Research Laboratories, New York, N. Y.
 Forbes Varnish Co., Cleveland, Ohio.
 Ford Motor Co., Dearborn, Mich.
 Forest Products Chemical Co., Memphis, Tenn.
 Formica Insulation Co., Cincinnati, Ohio.
 Fort Lauderdale Milling Co., Fort Lauderdale, Fla.
 Fortune Bros. Brewery, Chicago, Ill.
 Fort Worth Laboratories, Fort Worth, Tex.
 Fouke Fur Co., St. Louis, Mo.
 Fox Films Laboratory, Los Angeles, Calif.
 Freudenheim, Mendel E., Laboratories, New York, N. Y.
 Friedman Bag Co., Twin Falls, Idaho.
 Fritzsche Bros., New York, N. Y.
 Froedert Grain & Malt Co., Milwaukee, Wis.
 Fruit and Vegetable Standardization, Phoenix, Ariz.
 Fruit Industries Ltd., San Francisco, Calif.
 Fruit Industry of Washington, Yakima, Wash.
 Fruitland Cooperative Cannery, Fruitland, Idaho.
 Fuller, Henry C., Washington, D. C.
- G
- Gabriel Co., Cleveland, Ohio.
 Gaffney Manufacturing Co., Gaffney, S. C.
 Gair Cartons, Inc., Piermont, N. Y.
 Gair, Robert Co., New York, N. Y.
 Gaither Chemical Works, Nashville, Tenn.
 Gallun, A. F. & Sons, Milwaukee, Wis.
 G. and A. Laboratories, Savannah, Ga.
 Gardner-Richardson Co., Lockland, Ohio.
 Gaylord Container Corporation, Bogalusa, La.
 Geary, E. A., Klamath Falls, Oreg.
 General Electric Co., Lynn, Mass.; New York, N. Y.; Pittsfield, Mass.; Schenectady, N. Y.
 General Foods Corporation, Battle Creek, Mich.; Boston, Mass.; Evansville, Ind.; Hoboken, N. J.; New York, N. Y.
 General Ice Cream Corporation, Schenectady, N. Y.
 General Mills, Inc., Minneapolis, Minn.
 General Motors Co., Dayton, Ohio; Detroit, Mich.
 General Plastics, Inc., North Tonawanda, N. Y.
 Georgia Agricultural Experiment Station, Experiment, Ga.
 Georgia, University of, Athens, Ga.
 Georgia University, System of, Atlanta, Ga.
 Gephart, Frank C., New York, N. Y.
 Gerli, E., Co., New York, N. Y.
 Giannini Foundation, Berkeley, Calif.
 Gibbs & Co., Baltimore, Md.
 Glidden Co., Cleveland, Ohio; Jacksonville, Fla.; San Francisco, Calif.
 Globe Knitting Co., Grand Rapids, Mich.
 Globe Milling & Grain Co., San Francisco, Calif.
 Glyco Products Co., Inc., New York, N. Y.
 Godchaux Sugars, Inc., New Orleans, La.
 Golden State Milk Products Co., San Francisco, Calif.
 Goldsmith Leather Co., Newark, N. J.
 Gonzaga University, Spokane, Wash.
 Goodall Co., Sanford, Maine.
 Good Bros. Leather Co., Newark, N. J.
 Good Housekeeping Institute, New York, N. Y.
 Goodrich, B. F., Co., Akron, Ohio; Los Angeles, Calif.
 Goodyear Tire & Rubber Co., Akron, Ohio.
 Grand Rapids Varnish Corporation, Grand Rapids, Mich.
 Grasselli Chemicals Department, E. I. du Pont de Nemours Co., Inc., Cleveland, Ohio.
 Gray & Co., Portland, Oreg.
 Gray, Gore & Daniel, Inc., Gastonia, N. C.
 Gray, Joseph L., Lake City, Fla.
 Great Western Sugar Co., Denver, Colo.
 Griess-Pfleger Tanning Co., Waukegan, Ill.
 Griffith Laboratories, Chicago, Ill.
 Grosvenor, William M., Laboratories, Inc., New York, N. Y.
 Grower's Fertilizer Co., San Francisco, Calif.
 Gulf Mobile & Northern Railroad Co., Jackson, Miss.
 Gulf Research & Development Co., Harnarville, Pa.
 Gutman & Co., Chicago, Ill.

H

Hackmeister, Inc., Pittsburgh, Pa.
 Haering, D. W., & Co., Inc., Chicago, Ill.
 Hammermill Paper Co., Erie, Pa.
 Hanes, P. H., Knitting Co., Winston Salem, N. C.
 Happy Holme Farms, Lodi, Calif.
 Harbor Plywood Corporation, Hoquiam, Wash.
 Harlan Associates, San Francisco, Calif.
 Harris Laboratories, Tuckahoe, N. Y.
 Harshaw Chemical Co., Cleveland, Ohio.
 Hartford Rayon Corporation, Rocky Hill, Conn.
 Hart Products Corporation, Woodbridge, N. J.
 Harvard University, Cambridge, Mass.
 Haskellite Manufacturing Corporation, Grand Rapids, Mich.
 Heinz, H. J. Co., Pittsburgh, Pa.
 Henderson Sugar Refining Co., New Orleans, La.
 Hercules Powder Co., Brunswick, Ga.; Kalamazoo, Mich.; Wilmington, Del.
 Hershey Chocolate Corporation, Hershey, Pa.
 Herstein Laboratories, Inc., New York, N. Y.
 Herty Foundation Laboratories, Savannah, Ga.
 Herzog Laboratories, Gainesville, Fla.
 Hewlett Bros. Co., Salt Lake City, Utah.
 Heyden Chemical Corporation, New York, N. Y.
 Hicks Rubber Co., Waco, Tex.
 Hilo Varnish Corporation, Brooklyn, N. Y.
 Hilton-Davis Chemical Co., Cincinnati, Ohio.
 Hochstadter Laboratories, Inc., New York, N. Y.
 Holeproof Hosiery Co., Milwaukee, Wis.
 Hollingsworth & Vose Co., East Walpole, Mass.; West Groton, Mass.
 Hollister & Stier Laboratories, Spokane, Wash.
 Holly Sugar Corporation, Stockton, Calif.
 Homasote Co., Trenton, N. J.
 Hood River Apple Growers Association, Hood River, Ore.
 Hood River Distillers, Inc., Hood River, Ore.
 Hood Rubber Co., Inc., Watertown, Mass.
 Hooper, William & Sons, Philadelphia, Pa.
 Hoppenstedt, A. W., Laboratory, Buffalo, N. Y.
 Horst, E. Clemens Co., San Francisco, Calif.
 Houston Laboratories, Houston, Tex.
 Howard, J. W. & A. P., Co., Corry, Pa.

Hubinger Co., Keokuk, Iowa.
 Hubschman, E., & Sons, Philadelphia, Pa.
 Hunt-Rankin Leather Co., Peabody, Mass.
 Hurd, Fred, Packing Co., Roseburg, Calif.
 Hurst Laboratories, St. Petersburg, Fla.
 Hutchison, W. H., & Son, Inc., Chicago, Ill.
 Huyck, F. C., & Sons, Kenwood Mills, Rensselaer, N. Y.

I

Idaho Branch Agricultural Experiment Station, Parina, Idaho.
 Idaho Bureau of Crop Statistics and Commission of Agriculture, Boise, Idaho.
 Idaho Canning Co., Payette, Idaho.
 Idaho Department of Agriculture, Boise, Idaho.
 Idaho State Grange, Caldwell, Idaho.
 Idaho, University of, and Agricultural Experiment Station, Moscow, Idaho.
 Igleheart Bros., Inc., Evansville, Ind.
 Illinois Paint Works, Chicago, Ill.
 Illinois State Water Survey, Urbana, Ill.
 Illinois, University of, and Agricultural Experiment Station, Urbana, Ill.
 Imperial County Agricultural Extension Service, El Centro, Calif.
 Independent Biscuit Manufacturers Co., Technical Institute, Chicago, Ill.
 Indiana Agricultural Experiment Station and Purdue University, LaFayette, Ind.
 Indiana, University of, Bloomington, Ind.
 Indian Orchard Corporation, Indian Orchard, Mass.
 Industrial Alcohol Institute, Washington, D. C.
 Industrial By-Products & Research Corporation, Philadelphia, Pa.
 Industrial Hygiene Laboratory, New York, N. Y.
 Industrial Rayon Corporation, Cleveland, Ohio.
 Industrial Research Laboratories, Muskegon, Mich.
 Institute of American Meat Packers, Chicago, Ill.
 Institute of American Poultry Industries, Chicago, Ill.
 Institute of Paper Chemistry, Appleton, Wis.
 International Milling Co., Minneapolis, Minn.
 International Paper Co., South Glens Falls, N. Y.
 International Shoe Co., St. Louis, Mo.
 Iowa State College of Agriculture and Mechanic Arts and Agricultural Experiment Station, Ames, Iowa.
 Iowa, University of Iowa City, Iowa.
 Ironsides, Co. Columbus, Ohio.
 Irvington Varnish & Insulating Co., Irvington, N. J.

J

Jackson, H. G., Providence, R. I.
 Jean, J. W., Altadena, Calif.
 Jenkins, Geo. O., Co., Bridgewater, Mass.
 Johns Hopkins University, Baltimore, Md.
 Johnson, S. C. & Son, Inc., Racine, Wis.
 Johnston Mills, Charlotte, N. C.
 Jones, Fred F., Miami, Fla.
 Jones, William H., & Co. Dallas, Tex.
 Judd Paper Co., Holyoke, Mass.

K

Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich.
 Kansas City Testing Laboratory, Kansas City, Mo.
 Kansas Milling Co., Wichita, Kans.
 Kansas State College of Agriculture and Applied Science and Agricultural Experiment Station, Manhattan, Kans.
 Kansas, University of, Lawrence, Kans.
 Kay & Ess Co., Dayton, Ohio.
 Kellogg Co., Battle Creek, Mich.
 Kem Products Co., Inc., Newark, N. J.
 Kendall Mills, Walpole, Mass.
 Kentucky, University of, and Agricultural Experiment Station, Lexington, Ky.
 Kessler Chemical Corporation, Philadelphia, Pa.
 Kettering, Charles F., Dayton, Ohio.
 Kettering, Charles F., Foundation, Yellow Springs, Ohio.
 Keystone Steel & Wire Co., Peoria, Ill.
 Killian Research Laboratories, Inc., New York, N. Y.
 Kind & Knox Gelatine Co., Camden, N. J.
 Kistler Leather Co., Lock Haven, Pa.
 Klamath Potato Growers Association, Klamath Falls, Ore.
 Klearflax Linen Looms, Inc., Duluth, Minn.
 Knudsen Creamery Co., Los Angeles, Calif.
 Kohnstamm & Co., Inc., New York, N. Y.
 Kraft-Phoenix Corporation, Chicago Ill.
 Krause, Charles A., Milling Co., Milwaukee, Wis.
 Kroger Grocery & Baking Co., Cincinnati, Ohio.
 Kugler, L. T., Laboratory, Lambertville, N. J.

L

Laboratory of Vitamin Technology, Chicago, Ill.
 La France Manufacturing Co., New York, N. Y.
 Lakeland Highlands Canning Co., Highlands City, Fla.

Lambert Pharmacal Co., St. Louis Mo.
 Land O'Lakes, Minneapolis, Minn.
 Larkin Co., Inc., Buffalo, N. Y.
 Laros, R. K., Silk Co., Bethlehem, Pa.
 Lash Co., Anaheim, Calif.
 Laub's, George, Sons, Buffalo, N. Y.
 Laucks, I. F., Inc., Seattle, Wash.
 Laundryowners' National Association, Joliet, Ill.
 LaWall & Harrisson, Philadelphia, Pa.
 Lawrence, A. C., Leather Co., Peabody, Mass.
 Lazell, E. W., Laboratory, Portland, Ore.
 Leas & McVitty, Inc., Philadelphia, Pa.
 Lehigh University, Bethlehem, Pa.
 Leland Stanford University, Palo Alto, Calif.
 Lever Bros. Co., Cambridge, Mass.; Hammond, Ind.
 Libby, McNeill & Libby, Chicago, Ill.
 Liberty Mills, San Antonio, Tex.
 Lilly & Co., Eli, Indianapolis, Ind.
 Little, Arthur D., Inc., Cambridge, Mass.; Washington, D. C.
 Livingston, William R., Oxnard, Calif.
 Log Cabin Syrup, Hoboken, N. J.
 Long, W. E., Co., Chicago, Ill.
 Loose-Wiles Biscuit Co., Long Island City, N. Y.
 Los Angeles Chemical Co., South Gate, Calif.
 Los Angeles County Farm Bureau, Los Angeles, Calif.
 Los Angeles Soap Co., Los Angeles, Calif.
 Los Angeles Testing Laboratory, Los Angeles, Calif.
 Louisiana A. A. A. Committee, Plain Dealing, La.
 Louisiana Farm Bureau, Lake Charles, La.
 Louisiana State University and Agricultural and Mechanical College and Agricultural Experiment Station, University, La.
 Lowe Bros. Co., Dayton, Ohio.
 Lowell Textile Institute, Lowell, Mass.
 Lower Columbia Dairy Association, Astoria, Ore.
 Lucas, H. G., Brownwood, Tex.
 Lucas, John, & Co., Inc., Philadelphia, Pa.
 Lucidol Corporation, Buffalo, N. Y.
 Lund, A. A., & Associates, New York, N. Y.
 Lurton Co., Pensacola, Fla.

Mc

McCloske Varnish Co., Philadelphia, Pa.
 McCormick & Co., Inc., Baltimore, Md.
 McDermitt, T. W., Los Angeles, Calif.
 McFadden, A. J., Santa Ana, Calif.
 McGean Chemical Co., Cleveland, Ohio.
 McGee Dean & Co., Leland, Miss.

McGraw-Hill Book Co., New York, N. Y.; San Francisco, Calif.
McSweeney, J. G., Temecula, Calif.

M

Maas & Waldstein Co., Newark, N. J.
Maas Laboratories, Los Angeles, Calif.
Macy, R. H., & Co., Inc., New York, N. Y.
Maine Pomological Society, Orono, Maine.
Maine Potato Growers & Shippers Committee, Inc., Presque Isle, Maine.
Maine Potato Growers, Inc., Presque Isle, Maine.
Maine, University of, and Agricultural Experiment Station, Orono, Maine.
Makepeace, J. C., Wareham, Mass.
Maling, B. E., Co., Inc., Hillsboro, Oreg.
Mallinckrodt Chemical Works, St. Louis, Mo.
Malt Diatase Co., Chicago, Ill.
Manning Paper Co., Inc., John A., Green Island, N. Y.
M. & R. Dietetic Laboratories, Inc., Columbus, Ohio.
Manufacturing Chemists Association of the United States, Washington, D. C.
Marathon Chemical Co., Rothschild, Wis.
Marshall Field & Co., Spray, N. C.
Martin Dennis Co., Newark, N. J.
Maryland Fertilizer Manufacturing Co., Baltimore, Md.
Maryland State Grange, Bel Air, Md.
Maryland, University of and Agricultural Experiment Station, College Park, Md.
Maryville College, Maryville, Tenn.
Maselli, G., & Sons, Inc., Fresno, Calif.
Masonite Corporation, Laurel, Miss.
Massachusetts Institute of Technology, Cambridge, Mass.
Massachusetts State College and Agricultural Experiment Station, Amherst, Mass.
Mead Corporation, Lynchburg, Va.
Mead Corporation, Chillicothe, Ohio.
Mead Johnson & Co., Evansville, Ind.
Meigs, Basset & Slaughter, Inc., Philadelphia, Pa.
Mellon Institute, Pittsburgh, Pa.
Mennel Milling Co., Fostoria, Ohio.
Merck & Co., Rahway, N. J.
Merlie Papaya Products, Coconut Grove, Fla.
Merrell, William S., Co., Cincinnati, Ohio.
Metasap Chemical Co., Harrison, N. J.
Michigan Bakeries, Grand Rapids, Mich.
Michigan State College of Agriculture and Applied Sciences and Agricultural Experiment Station, East Lansing, Mich.
Michigan, University of, Ann Arbor, Mich.

Mifflin Chemical Corporation, Philadelphia, Pa.
Milkweed Products Development Corporation, Chicago, Ill.
Miller Freeman Publications, San Francisco, Calif.
Miller, Henry M., Jr., Paw Paw, W. Va.
Millers National Federation, Chicago, Ill.
Milliken & Farwell Co., New Orleans, La.
Milton Cooperative Dairy Corporation, Milton, Vt.
Miner Laboratories, Chicago, Ill.
Minnesota and Ontario Paper Co., Minneapolis, Minn.
Minnesota, University of, and Agricultural Experiment Station, Minneapolis, Minn.; St. Paul, Minn.
Minor Laboratory, Springfield, Mass.
Minute Tapioca Co., Inc., Orange, Mass.
Mississippi Department of Agriculture, Jackson, Miss.
Mississippi State College and Agricultural Experiment Station, State College, Miss.
Mississippi State Planning Commission, Jackson, Miss.
Mississippi, University of, Oxford, Miss.
Missouri Pacific Lines, Houston, Tex.
Missouri, University of, and Agricultural Experiment Station, Columbia, Mo.
Modern Miller, Chicago, Ill.
Monaghan Mills, Greenville, S. C.
Monite Waterproof Glue Co., Minneapolis, Minn.
Monsanto Chemical Co., Dayton, Ohio; Indian Orchard, Mass.; St. Louis, Mo.
Montana Department of Agriculture, Helena, Mont.; Missoula, Mont.
Montana State College and Agricultural Experiment Station, Bozeman, Mont.
Montana, University of, Bozeman, Mont.; Missoula, Mont.
Montgomery Ward & Co., Chicago, Ill.
Monticello Nurseries Co., Monticello, Fla.
Moody, H. N., New Orleans, La.
Morning Mills Co., Salt Lake City, Utah.
Morning Star, Nicol, Inc., New York, N. Y.
Moscow Idaho Seed Co., Moscow, Idaho.
Mountain Varnish & Color Works, Inc., Toledo, Ohio.
Mullin, Charles E., Huntingdon, Pa.
Muralo Co., Staten Island, New York, N. Y.
Mutual Citrus Products Co., Anaheim, Calif.
Mutual Orange Distributors, Redlands, Calif.

N

Nashua Gummed & Coated Paper Co., Nashua, N. H.

- National Adhesive Co., New York, N. Y.
 National Aniline & Chemical Co., Inc., New York, N. Y.
 National Association of Manufacturers, New York, N. Y.
 National Baking Co., Omaha, Nebr.
 National Biscuit Co., New York, N. Y.
 National Canners Association, Washington, D. C.
 National Cash Register Co., Dayton, Ohio.
 National Cereal Products Co., Chicago, Ill.
 National Cottonseed Products Association, Birmingham, Ala.; Dallas, Tex.; Memphis, Tenn.
 National Distillers Products Corporation, Cincinnati, Ohio; Peoria, Ill.
 National Farm Chemurgic Council, New York, N. Y.
 National Grange, Washington, D. C.
 National Lead Co., Brooklyn, N. Y.
 National Livestock and Meat Board, Chicago, Ill.
 National Oil Products Co., Inc., Harrison, N. J.
 National Paint, Varnish & Lacquer Association, Washington, D. C.
 National Products Co., Orlando, Fla.
 National Research Council, Madison, Wis., Washington, D. C.
 National Vulcanized Fibre Co., Yorklyn, Del.
 Natural Food Products Co., Orange, Calif.
 Naugatuck Chemical Co., Naugatuck, Conn.
 Nebraska, University of, and Agricultural Experiment Station, Lincoln, Nebr.
 Nelson, R. F., Richmond, Va.
 Neumann, R. & Co., Hoboken, N. J.
 Nevada Department of Agriculture, Reno, Nev.
 Nevada, University of, and Agricultural Experiment Station, Reno, Nev.
 New Bedford Textile School, New Bedford, Mass.
 New England Council, Boston, Mass.
 New England Laboratories, Springfield, Mass.
 New Hampshire, University of, and Agricultural Experiment Station, Durham, N. H.
 New Jersey Department of Agriculture, Trenton, N. J.
 New Jersey State College of Agriculture and Mechanic Arts and Agricultural Experiment Station of Rutgers University, New Brunswick, N. J.
 Newlords Sanitary Laboratories, Hartford, Conn.
 New Mexico College of Agriculture and Mechanic Arts and Agricultural Experiment Station, State College, N. Mex.
 New Mexico, University of Albuquerque, N. Mex.
 Newport Industries, Pensacola, Fla.
 New York Produce Exchange, New York, N. Y.
 New York State College of Agriculture and Agricultural Experiment Station at Cornell University, Ithaca, N. Y.
 New York Sugar Trade Laboratory, Inc., New York, N. Y.
 Nitragin Co., Inc., Milwaukee, Wis.
 Noble & Wood Machine Co., Hoosick Falls, N. Y.
 North American Rayon Corporation, Elizabethton, Tenn.
 North Carolina State College of Agriculture and Engineering and Agricultural Experiment Station, Raleigh, N. C.
 North Carolina, University of Chapel Hill, N. C.
 North Central Service Laboratory, Wenatchee, Wash.
 North Dakota Agricultural College and Agricultural Experiment Station, Fargo, N. Dak.
 Northern Pacific Railroad, Seattle, Wash.
 North Pacific Canners & Packers, Portland, Ore.
 North Pacific Cooperative Prune Exchange, Portland, Ore.
 North Pacific Grain Growers, Portland, Ore.
 Northwest Canners Association, Portland, Ore.
 Northwest Cherry Briners Association, Corvallis, Ore.
 Northwest Dried Fruit Association, Portland, Ore.
 Northwestern Fruit Exchange, Wenatchee, Wash.
 Northwestern Malt & Grain Co., Chicago, Ill.
 Northwestern Miller, Minneapolis, Minn.
 Northwestern Turkey Growers Association, Salt Lake City, Utah.
 Northwestern University, Evanston, Ill.
 Northwest Frozen Foods Association, Portland, Ore.
 Northwest Testing Laboratory, Seattle, Wash.
 Northwest Vinegar Manufacturing Association, Portland, Ore.
 Norton, E. W., Birmingham, Ala.
 Nowak Chemical Laboratories, St. Louis, Mo.
 Nubian Paint & Varnish Co., Chicago, Ill.
 Nutter, William S., Sanford, Maine.
- O
- Ohio Agricultural Experiment Station, Wooster, Ohio.
 Ohio State University, Columbus, Ohio.

Ohio State University Research Foundation, Columbus, Ohio.
 Oklahoma Agricultural and Mechanical College and Agricultural Experiment Station, Stillwater, Okla.
 Oklahoma Farm Chemurgic Council, Oklahoma City, Okla.
 Oklahoma, University of, Norman, Okla.
 Old Colony Envelope Co., Westfield, Mass.
 Olmsted, George O., Indian River City, Fla.
 Oregon Brewers Association, Portland, Oreg.
 Oregon Medical School, Portland, Oreg.
 Oregon Milk Control Board, Portland, Oreg.
 Oregon State Agricultural College and Agricultural Experiment Station, Corvallis, Oreg.
 Oregon State Grange, Portland, Oreg.
 Osgood, George, Co., Cincinnati, Ohio.
 Oswald & Taube Co., Cincinnati, Ohio.
 Orthmann Laboratories, Inc., Milwaukee, Wis.
 Oxford Paper Co., Rumford, Maine.

P

Pacific Chemical Co., Los Angeles, Calif.
 Pacific Chemical Laboratories, San Francisco, Calif.
 Pacific Coast Wool Manufacturers Association, Portland, Oreg.
 Pacific Cooperative Poultry Producers, Portland, Oreg.
 Pacific Mills, Lyman, S. C.; New York, N. Y.
 Pacific Northwest Fruit, Inc., Yakima, Wash.
 Pacific Nut Oil Co., Los Angeles, Calif.
 Pacific Rural Press Co., San Francisco, Calif.
 Pacific States Butter, Egg, Cheese & Poultry Association, San Francisco, Calif.
 Pacific States Livestock Marketing Association, San Francisco, Calif.
 Pacific Testing Laboratory, Seattle, Wash.
 Papaya Development Co., Tampa, Fla.
 Paper Makers Chemical Corporation, Marrero, La.
 Paraffine Cos., Inc., Emeryville, Calif.
 Parke-Davis & Co., Detroit, Mich.
 Patch, E. L., Co., Boston, Mass.
 Paul, O. A., Chicago, Ill.
 Penick and Ford, Ltd., Inc., Cedar Rapids, Iowa; Harvey, La.
 Penick, S. B. & Co., New York, N. Y.
 Penney, J. C., Co., Inc., New York, N. Y.
 Pennsylvania Cannery Association, Hanover, Pa.
 Pennsylvania Department of Agriculture, Harrisburg, Pa.
 Pennsylvania Potato Growers Association, Doylestown, Pa.
 Pennsylvania State College and Agricultural Experiment Station, State College, Pa.
 Pennsylvania Sugar Co., Philadelphia, Pa.
 Pettigrew, Kenneth, Rocky Ford, Colo.
 Pfanstiehl Chemical Co., Waukegan, Ill.
 Pfizer, Charles & Co., Inc., Brooklyn, N. Y.
 Phelps, David, San Francisco, Calif.
 Philadelphia Textile School, Philadelphia, Pa.
 Phillips, Dr. P., Co., Orlando, Fla.
 Pickard, Glenn H., Chicago, Ill.
 Piedmont Print Works, Taylors, S. C.
 Pieser-Livingston, Chicago, Ill.
 Pillsbury Flour Mills, Minneapolis, Minn.
 Pioneer Flintkote Co., Los Angeles, Calif.
 Pioneer United Dairyman's Association, Everett, Wash.
 Pittsburgh Plate Glass Co., Milwaukee, Wis.; Newark, N. J.; Pittsburgh, Pa.
 Planters Nut & Chocolate Co., Suffolk, Va.
 Plant Reduction Corporation, Live Oak, Fla.
 Plaskon Co., Toledo, Ohio.
 Plastic Research Co., Winchester, Mass.
 Pollard, Arthur, Knoxville, Tenn.
 Pomona Products Co., Griffin, Ga.
 Porro Biological Laboratories, Tacoma, Wash.
 Portland Gas & Coke Co., Portland, Oreg.
 Poultry Producers of Central California, San Francisco, Calif.
 Poultry Science Association, Pullman, Wash.
 Poultrymen's Cooperative Association, Los Angeles, Calif.
 Pratt & Lambert, Inc., Buffalo, N. Y.
 Premier-Pabst Corporation, Milwaukee, Wis.; Peoria, Ill.
 Prevatt, Carolton, Clewiston, Fla.
 Princeton University, Princeton, N. J.
 Process Engineers, Inc., Mount Vernon, N. Y.
 Procter Ellison Co., Elkland, Pa.
 Procter & Gamble Co., Ivorydale, Ohio.
 Producers Cottonseed Oil Co., Fresno, Calif.
 Proximity Manufacturing Co., Greensboro, N. C.
 Pruitt, L. E., Laboratory, Wenatchee, Wash.
 Pulp Products Co., Inc., Masillon, Ohio.
 Purdue University, Lafayette, Ind.
 Purity Bakeries, Chicago, Ill.
 Pyramid Process Co., Inc., East Rochester, N. Y.
 Pyroxylin Products, Inc., Chicago, Ill.

Pyrrole Products Corporation, Portsmouth, Ohio.

Q

Quaker Oats, Chicago, Ill.

Quality Bakers of America, New York, N. Y.

R

Raffi & Swanson, Inc., Chelsea, Mass.

Rafton Laboratories, Inc., Andover, Mass.

Ralston-Purina Co., St. Louis, Mo.

Ramie Corporation, Miami, Fla.

Rapinwax Paper Co., Minneapolis, Minn.

Rayonnier, Inc., Seattle, Wash.

Redman Scientific Co., San Francisco, Calif.

Red Star Yeast Co., Milwaukee, Wis.

Reed College, Portland, Oreg.

Reed Laboratories, New York, N. Y.

Rees, Hans, & Sons, Inc., Asheville, N. C.

Reichhold Chemical, Inc., Detroit, Mich.

Reid Murdoch Co., Salem, Oreg.

Reiff, Charles O., Marianna, Fla.

Reilly Tar & Chemical Corporation, Indianapolis, Ind.

Republic Cotton Mills, Great Falls, S. C.

Research Corporation, Bound Brook, N. J.

Reynolds Research Corporation, South Kearny, N. J.

Reynolds, R. J., Tobacco Co., Winston-Salem, N. C.

Rhoads, J. E., & Sons, Wilmington, Del.

Rhode Island School of Design, Providence, R. I.

Rhode Island State College and Agricultural Experiment Station, Kingston, R. I.

Rice Growers Association of California, Sacramento, Calif.

Rice Institute, Houston, Tex.

Rice Millers Association, New Orleans, La.

Richey Gilbert Co., Yakima, Wash.

Richmond Chase Co., San Jose, Calif.

Rinshed-Mason Co., Detroit, Mich.

Rio Grande Valley Citrus Exchange, Weslaco, Tex.

Rit Products Corporation, Chicago, Ill.

Riverside and Dan River Cotton Mills, Danville, Va.

Riverside Chemical Co., Inc., North Tonawanda, N. Y.

Robeson Process Co., Erie, Pa.

Rockefeller Institute, New York, N. Y.; Princeton, N. J.

Rocky Ford Science Club, Rocky Ford, Colo.

Rocky Mountain Packing Corporation, Salt Lake City, Utah.

Rogers Paper Manufacturing Corporation, Manchester, Conn.

Rohn & Haas, Bristol, Pa.; Philadelphia, Pa.

Rollins College, Winter Park, Fla.

Rosenberg Brothers, Inc., San Francisco, Calif.

Ross Packing Co., Selah, Wash.

Royal Baking Powder Co., Brooklyn, N. Y.

Royal Manufacturing Co. of Duquesne, Chicago, Ill.

Rueping, Fred, Leather Co., Fond du Lac, Wis.

Russell Miller Milling Co., Minneapolis, Minn.

Rutgers University, New Brunswick, N. J.

Ryan, J. J., & Sons, Greenville, S. C.

Ryan Seed Co., Rocky Ford, Colo.

S

Salem College, Winston-Salem, N. C.

Salt Lake Milk Producers Association, Salt Lake City, Utah.

Salt River Valley Water Users Association, Phoenix, Ariz.

San Antonio Analytical Laboratories, San Antonio, Tex.

Sanford Mill "L," Reading, Mass.

Savannah Sugar Refinery Corporation, Savannah, Ga.

Saxon Mills, Spartanburg, S. C.

Schering Corporation, Bloomfield, N. J.

Schlitz, Jos., Brewing Co., Milwaukee, Wis.

Schoffelmayer, Victor H., Dallas, Tex.

Schuckl & Co., Inc., Sunnyvale, Calif.

Schwarz Laboratories, New York, N. Y.

Schwill Malting Co., Chicago, Ill.

Scott Paper Co., Chester, Pa.

Seagram, Jos. E., & Sons, Inc., Louisville, Ky.

Sealright Co., Fulton, N. Y.

Sealtest, Inc., Baltimore, Md.

Sears, Roebuck & Co., Chicago, Ill.

Seattle Dairymen's Association, Seattle, Wash.

Seton Leather Co., Newark, N. J.

Sewell, S. Brown & Co., Los Gatos, Calif.

Shark Industries, Hollywood, Fla.

"Shaw Family," San Jose, Calif.

Shearer Fruit and Poultry Farms, Vinemont, Pa.

Sheffield By-Products Co., Hobart, N. Y.

Shell Chemical Co., San Francisco, Calif.

Shell Development Co., Emeryville, Calif.

Sherwin-Williams Co., Berkeley, Calif.; Chicago, Ill.; Cleveland, Ohio.

Shilstone Testing Laboratories, New Orleans, La.

Shumaker, O. Co., Rocky Ford, Colo.

- Siebel, E. A., Chicago, Ill.
 Siebel, J. E., Sons & Co., Chicago, Ill.
 Sirrine, J. E., & Co., Greenville, S. C.
 Skinner & Sherman, Inc., Boston, Mass.
 Sloane-Blabon Corporation, Trenton, N. J.
 S. M. A. Corporation, Cleveland, Ohio.
 Smith, Alexander & Sons Carpet Co., Yonkers, N. Y.
 Smith, Emery & Co., San Francisco, Calif.
 Smith-Emery Co., Los Angeles, Calif.
 Smyre Manufacturing Co., Ranlo, N. C.
 Society of American Bacteriologists, San Francisco, Calif.
 Society of American Foresters, New Hampshire.
 South Carolina Agricultural Experiment Station, Clemson, S. C.
 South Carolina, University of, Columbia, S. C.
 South Coast Corporation, New Orleans, La.
 South Dakota State College of Agriculture and Mechanic Arts and Agricultural Experiment Station, Brookings, S. Dak.
 Southern Bleachery and Piedmont Print Works, Taylors, S. C.
 Southern Chemical Cotton Co., Chattanooga, Tenn.
 Southern Combed Yarn Spinners Association, Gastonia, N. C.
 Southern Cotton Oil Co., Gretna, La.; Savannah, Ga.
 Southern Methodist University, Dallas, Tex.
 Southern Oregon Sales, Inc., Medford, Oreg.
 Southern Pacific Co., San Francisco, Calif.
 Southport Mills, Ltd., Inc., New Orleans, La.
 South Port Paint Co., Savannah, Ga.
 South Texas Cotton Oil Co., Houston, Tex.
 Southwestern University, Memphis, Tenn.
 Soybean Processors Association, Chicago, Ill.
 Spencer Kellogg & Sons, Inc., Buffalo, N. Y.; Los Angeles, Calif.
 Sperry Flour Co., San Francisco, Calif.
 Sperry Mills, Spokane, Wash.
 Springs Mills, Chester, S. C.
 Squibb, E. R., & Sons, Brooklyn, N. Y.; New Brunswick, N. J.
 Staley, A. E., Manufacturing Co., Decatur, Ill.
 Standard-Coosa-Thatcher Co., Chattanooga, Tenn.
 Standard Milling Co., Chicago, Ill.
 Standard Oil Co. of Indiana, Chicago, Ill.
 Stanley Chemical Co., East Berlin, Conn.
 Staple Cotton Cooperative Association, Greenwood, Miss.
 Stauffer Chemical Co., San Francisco, Calif.
 Stearns, Frederick & Co., Detroit, Mich.
 Steen, John A., Varnish Co., Chicago, Ill.
 Stein-Hall Company, Inc., Charlotte, N. C.
 Steph Laboratories, Milwaukee, Wis.
 Sterling Fibre Co., Waltham, Mass.
 Sterling Michigan Corporation, Chelsea, Mich.
 Stevens, J. P. & Co., Inc., New York, N. Y.
 Stevens, M. T., & Sons Co., North Andover, Mass.
 Stone, M. R. Co., Yakima, Wash.
 Strathmore Paper Co., West Springfield, Mass.
 Strong Cobb Co., Inc., Cleveland, Ohio.
 Suchar Process Corporation, New York, N. Y.
 Sucre Blanc, New York, N. Y.
 Suffolk Oil Mills, Inc., Suffolk, Va.
 Sun-Maid Raisin Growers Association, Fresno, Calif.
 Surpass Leather Co., Philadelphia, Pa.
 Sutherland, D. Manson, Jr., Trenton, N. J.
 Suwannee Moss Co., Live Oak, Fla.
 Swann & Co., Birmingham, Ala.
 Sweet Potato Growers Association, Sunset, La.
 Swift & Co., Chicago, Ill.; North Portland, Oreg.; San Francisco, Calif.
 Sylvania Industrial Corporation, Fredericksburg, Va.

T

- Takamine Laboratory, Inc., Clifton, N. J.
 Tanners Council of America, New York, N. Y.
 Tanner's Hide Bureau, New York, N. Y.
 Tannin Corporation, Bethany, Conn.; Wilmington, Del.
 Taylor Seed Co., Quincy, Fla.
 Teas Extract Co., Andrews, N. C.; Nashville, Tenn.
 Tennessee Eastman Corporation, Kingsport, Tenn.
 Tennessee Products Corporation, Wrigley, Tenn.
 Tennessee, University of and Agricultural Experiment Station, Knoxville, Tenn.
 Texas Agricultural and Mechanical College and Agricultural Experiment Station, College Station, Tex.
 Texas Christian University, Fort Worth, Tex.
 Texas Cottonseed Crushers Association, Dallas, Tex.
 Texas Planning Board, Austin, Tex.
 Texas Technological College, Lubbock, Tex.
 Texas, University of, Austin, Tex.

Textile Testing and Research Laboratories, New York, N. Y.
 The Dalles Cooperative Growers, The Dalles, Oreg.
 Thomas and Hochwalt Laboratories, Dayton, Ohio.
 Thompson & Lichtner Co., Inc., Boston, Mass.
 Thornton-Walker Co., Tampa, Fla.
 Thresher Varnish Co., Dayton, Ohio.
 Tobacco By-Products & Chemical Corporation, Richmond, Va.
 Toch Bros., Inc., Port Richmond, Staten Island, N. Y.
 Traders Compress Co., Fort Worth, Tex.; Memphis, Tenn.
 Trinity Laboratories, Austin, Tex.
 Trinity University, Waxahachie, Tex.
 Tropical Paint & Oil Co., Cleveland, Ohio.
 Trostel, Albert, & Sons, Co., Milwaukee, Wis.
 Trubek Laboratories, East Rutherford, N. J.
 Trubenizing Process Corporation, New York, N. Y.
 Truesdail Laboratories, Inc., Los Angeles, Calif.
 Tubize-Chatillon Corporation, Rome, Ga.
 Tulane University, New Orleans, La.
 Turco Products, Inc., Los Angeles, Calif.
 Tuskegee Institute, Tuskegee, Ala.
 Twining Laboratories, Fresno, Calif.

U

Union Bleachery, Greenville, S. C.
 Union Carbide & Carbon Corporation, New York, N. Y.
 Union Fruit Producers, Wenatchee, Wash.
 Union Paste Co., Medford, Mass.
 Union Starch & Refining Co., Granite City, Ill.
 United Dairymen's Association, Seattle, Wash.
 United Fruit Co., New York, N. Y.
 United States Chamber of Commerce, Washington, D. C.
 United States Envelope Co., Worcester, Mass.
 United States Finishing Co., Norwich, Conn.
 United States Government:
 Agriculture Department: Agricultural Adjustment Administration, Bureau of Agricultural Economics, Bureau of Agricultural Engineering, Bureau of Animal Industry, Bureau of Biological Survey, Bureau of Chemistry and Soils, Bureau of Dairy Industry, Bureau of Entomology and Plant Quarantine,

United States Government—Contd.
 Food and Drug Administration, Forest Service, Bureau of Home Economics, Bureau of Plant Industry, Office of Experiment Stations, Secretary's Office.
 Commerce Department: Bureau of Fisheries, National Bureau of Standards.
 Navy Department.
 Smithsonian Institution.
 Tennessee Valley Authority.
 Treasury Department: Bureau of Narcotics, National Institute of Health.
 War Department.
 United States Gypsum Co., Chicago, Ill.; St. Joseph, Mo.
 United States Industrial Alcohol Co., Newark, N. J.; New Orleans, La.; New York, N. Y.
 United States Leather Co., Ridgway, Pa.
 United States Malt Association, Chicago, Ill.
 United States Playing Card Co., Norwood, Ohio.
 United States Rubber Co., Passaic, N. J.
 United States Rubber Products Inc., Hogansville, Ga.; Winnsboro, N. C.
 United States Sugar Corporation, Clewiston, Fla.
 United States Testing Co., Inc., Hoboken, N. J.
 United States Tobacco Co., Nashville, Tenn.
 University of Chicago, Chicago, Ill.
 University of Cincinnati, Cincinnati, Ohio.
 University of Dayton, Dayton, Ohio.
 University of Louisville, Louisville, Ky.
 University of Pittsburgh, Pittsburgh, Pa.
 University of Santa Clara, Santa Clara, Calif.
 University of Southern California, Los Angeles, Calif.
 Upjohn Co., Kalamazoo, Mich.
 Upson Co., Lockport, N. Y.
 Utah Department of Agriculture, Salt Lake City, Utah.
 Utah Farms Bureau, Salt Lake City, Utah.
 Utah-Idaho Sugar Corporation, Salt Lake City, Utah.
 Utah Poultry Producers Cooperative Association, Salt Lake City, Utah.
 Utah State Agricultural College and Agricultural Experiment Station, Logan, Utah.
 Utah, University of, Salt Lake City, Utah.
 Utah Wool Marketing Association, Salt Lake City, Utah.

V

Valentine & Co., Brooklyn, N. Y.
 Valentine's Meat Juice Co., Richmond, Va.
 Valentine Sugars, Lockport, La.
 Van Camp's, Inc., Indianapolis, Ind.
 Van Cleef Bros., Chicago, Ill.
 Vanderbilt, R. T. Co., E. Norwalk, Conn.
 Vanderbilt University, Nashville, Tenn.
 Van Schaack Bros. Chemical Works, Chicago, Ill.
 Vegetable Growers Association of America, Columbus, Ohio.
 Vegetable Oil Products, Wilmington, Calif.
 Vego-Hair Manufacturing Co., Gainesville, Fla.
 Vermont Extension Service, Burlington, Vt.
 Vermont, University of, and State Agricultural College and Agricultural Experiment Station, Burlington, Vt.
 Victor Chemical Works, Chicago, Ill.
 Vieux Carre Canning Co., New Orleans, La.
 Virginia Agricultural and Mechanical College and Polytechnic Institute and Agricultural Experiment Station, Blacksburg, Va.
 Virginia Department of Agriculture, Richmond, Va.
 Virginia Military Institute, Lexington, Va.
 Virginia, University of, Charlottesville, Va.
 Visking Corporation, Chicago, Ill.
 Vitab Corporation, Emeryville, Calif.
 Vitamin Products Co., Milwaukee, Wis.
 Vulcan Copper & Supply Co., Cincinnati, Ohio.
 Vulcan Corporation, Portsmouth, Ohio.

W

Washington Cannery Cooperative, Vancouver, Wash.
 Washington Cooperative Egg & Poultry Association, Seattle, Wash.
 Washington Cooperative Poultry Association, Seattle, Wash.
 Washington Creamery Operators, Seattle, Wash.
 Washington Packers, Inc., Sumner, Wash.
 Washington State College and Agricultural Experiment Station, Pullman, Wash.
 Washington State Cooperative Council, Seattle, Wash.
 Washington State Planning Council, Spokane, Wash.
 Washington University, St. Louis, Mo.
 Washington, University of, Seattle, Wash.
 Watervliet Paper Co., Watervliet, Mich.
 Watkins, J. R., Co., Memphis, Tenn.; Newark, N. J.; Winona, Minn.
 Weber Laboratories, M., Newark, N. J.
 Weinberg, Max, St. Louis, Mo.
 Wellington-Sears Co., New York, N. Y.
 Wellman, Harry R., Berkeley, Calif.
 Wenatchee Industrial Laboratories, Wenatchee, Wash.
 Wenatchee Valley Traffic Association, Wenatchee, Wash.
 Western Chemical Congress, San Francisco, Calif.
 Western Condensing Co., San Francisco, Calif.
 Western Growers Productive Association, Los Angeles, Calif.
 Western Paint & Varnish Co., New Duluth, Minn.
 Western Precipitation Corporation, Los Angeles, Calif.
 Western Reserve University, Cleveland, Ohio.
 Western Sugar Refinery, San Francisco, Calif.
 West Hickory Tanning Co., West Hickory, Pa.
 West Point Manufacturing Co., West Point, Ga.
 West Virginia Pulp & Paper Co., Tyrone, Pa.
 West Virginia State Horticultural Society, Martinsburg, W. Va.
 West Virginia, University of, and Agricultural Experiment Station, Morgantown, W. Va.
 Weyerhaeuser Timber Co., Longview, Wash.
 Weyl-Zuckerman & Co., Stockton, Calif.
 White Corn Millers Federation, Chicago, Ill.
 Whitten, J. O., Co., Winchester, Mass.
 Wichita University, Wichita, Kans.
 Widtsoe, John A., Salt Lake City, Utah.
 Wiedemann, H. E., St. Louis, Mo.

Wabash College, Crawfordsville, Ind.
 Wahl-Henius Institute, Chicago, Ill.
 Wahl Institute, Inc., Chicago, Ill.
 Walker, Hiram, & Sons, Peoria, Ill.
 Wallerstein Laboratories, New York, N. Y.
 Ward Baking Co., New York, N. Y.
 Wardway Paint Works, Chicago Heights, Ill.
 Ware Shoals Manufacturing Co., Ware Shoals, S. C.
 Warner-Jenkinson Manufacturing Co., St. Louis, Mo.
 Warren, S. D., Co., Cumberland Mills, Maine.
 Wasatch Chemical Co., Salt Lake City, Utah.
 Washburn & Wilson Seed Co., Moscow, Idaho.
 Washington and Lee University, Lexington, Va.

- Wilder, Ed, Lexington, Ky.
 Willamette Cherry Growers Association, Salem, Oreg.
 Williamson, B. F. & Co., Gainesville, Fla.
 Wilmington Testing and Research Laboratory, Wilmington, Del.
 Wilson & Bennett Manufacturing Co., Chicago, Ill.
 Wilson & Co., Inc., Chicago, Ill.
 Wilson, John Arthur, Buford, Ga.
 Wilson Milk Co., Indianapolis, Ind.
 Wilson, R. N., San Francisco, Calif.
 Wine Institute, San Francisco, Calif.
 Winthrop Chemical Co., Inc., Rensselaer, N. Y.
 Wisconsin State Board of Health, Madison, Wis.
 Wisconsin, University of, and Agricultural Experiment Station, Madison, Wis.
 Woburn Degreasing Co., of New Jersey, Harrison, N. J.
 Woodlawn Finishing Corporation, Pawtucket, R. I.
 Wood Products Institute, Washington, D. C.
 Woods Laboratories, Tacoma, Wash.
 Woonsocket Rayon Co., Woonsocket, R. I.
 Worden Laboratory and Library, Millburn, N. J.
 Wyandotte Worsted Co., Waterville, Maine.
 Wyoming State Department of Agriculture, Cheyenne, Wyo.
 Wyoming, University of, and Agricultural Experiment Station, Laramie, Wyo.
- Y
- Yakima Fruit Growers Association, Yakima, Wash.
 Yakima Industrial Laboratory, Yakima, Wash.
 Yakima Valley Traffic and Credit Association, Yakima, Wash.
 Yale University, New Haven, Conn.
- Z
- Zapon Laboratory-Atlas Co., Stamford, Conn.
 Zellers, G. F., Sons, Buffalo, N. Y.

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